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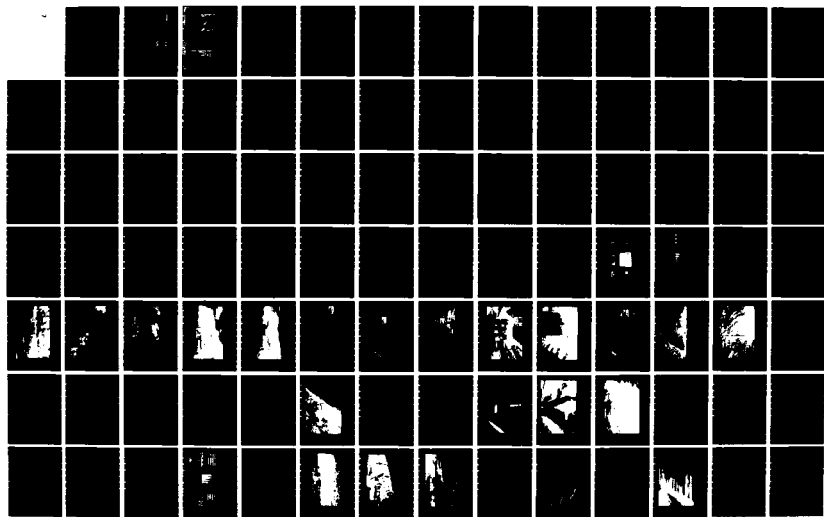
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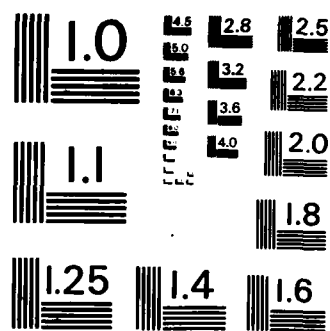
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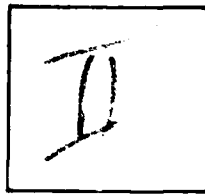


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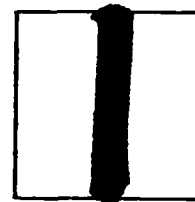
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Preliminary Investigation*

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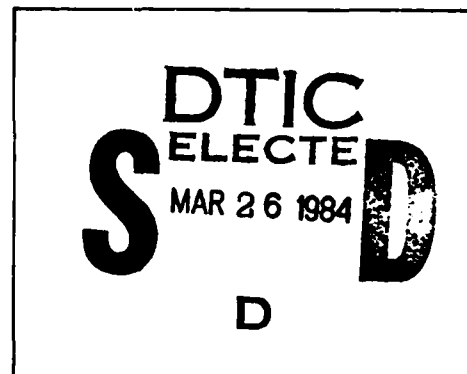
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PREFACE

This investigation was initiated jointly by the U. S. Army Mobility Equipment Research and Development Command (MERADCOM) and the Office, Chief of Engineers (OCE), U. S. Army. Project No. IL162733AH20-B8 (under 6.2 funds) entitled "Expedient Surfacing and Soil Investigation" and Project No. IL46372DG01-12 (under 6.3A funds) entitled "Tactical Bridge Access/Egress Investigation" were authorized by MERADCOM. The OCE authorized project was 4A762719AT40, Task 02, entitled "Techniques for Tactical Bridge Access/Egress."

The study was conducted during the period December 1977 through September 1978 by personnel of the Geotechnical Laboratory (GL), U. S. Army Engineer Waterways Experiment Station (WES), under the general supervision of Messrs. J. P. Sale, former Chief, GL, and Dr. D. C. Banks, Acting Chief, GL. Personnel actively engaged in planning and conducting the investigation were Messrs. R. L. Hutchinson (retired), W. L. McInnis (retired), H. L. Green, W. E. Willoughby, D. W. White, C. J. Smith, and G. L. Carr. The organization and consolidation of this report were accomplished by Messrs. Carr, Green, and H. M. Taylor, Jr.

Commanders and Directors of the WES during the conduct of this investigation were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. Fred R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic feet	0.02831685	cubic metres
degrees (angular)	0.01745329	radians
feet	0.3048	metres
inches	25.4	millimetres
miles (U. S. statute)	1.609344	kilometres
ounces (mass)	28.34952	grams
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6894.757	pascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square metres

TACTICAL BRIDGE ACCESS/EGRESS
PRELIMINARY INVESTIGATION

PART I: INTRODUCTION

Background

1. The U. S. Army may find itself at war in any of a variety of places and situations, fighting opponents that could vary from highly modern mechanized forces to light, irregular units in a remote part of the less-developed world. Wherever the battle begins, the U. S. Army must be equipped, organized, and trained to undertake appropriate military action.

2. Battle in central Europe is probably the most demanding mission the U. S. Army could be assigned (Headquarters, Dept. of the Army, 1976). Because the U. S. Army has large forces deployed in that area, the investigation described herein was conducted with test parameters (soil conditions and slopes) representative of field conditions to be encountered in central Europe.

3. River crossing operations are an integral part of land warfare. The lethality of modern weapons and the capability of larger enemy formations dictate that crossing forces reduce their vulnerability by maintaining inherent mobility. The object of any river crossing is to project combat power across a water obstacle while ensuring the integrity and momentum of the force. Therefore, whenever possible, whether in the offense or retrograde, rivers must be crossed in stride as a continuation of the operation using organic, existing, or expedient crossing means (Headquarters, Dept. of the Army, 1978).

4. The need for surfacing over marginal soil materials to expedite military traffic to and from hastily constructed bridge structures is apparent to ensure integrity and maintain the momentum of the force. How and where the Army goes in time of combat is greatly dependent upon planning, opportunity, and the possibility of improving stream crossings. The Army's experience and lessons learned are well documented, studied,

and used as a guide to develop more rapid methods or systems of crossing streams (Headquarters, Dept. of the Army, 1978). As the development of tactical bridge access/egress systems was under way, requirements for material, weight, cost, placement time, manpower, etc., were constantly changing. Hence, prior to undertaking the preliminary bridge access/egress research investigation, testing of current Department of Defense depot items was planned to determine to what degree depot items such as aircraft landing mats and/or membranes would meet these requirements.

5. The Headquarters, U. S. Army Materiel Development and Readiness Command (DARCOM) and Office, Chief of Engineers (OCE), U. S. Army, initially funded the tactical bridge access/egress investigation. The management of the project was through the U. S. Army Mobility Equipment Research and Development Command (MERADCOM), Ft. Belvoir, Va., who, with the U. S. Army Engineer Waterways Experiment Station (WES) and the U. S. Army Engineer School (USAES), developed a Letter of Agreement (LOA) (Welker, 1979). The draft LOA was used as a guideline by the WES to perform the research and engineering tests on depot materials in an attempt to meet the stated LOA requirements and to determine to what extent present inventory items meet some or all of these requirements.

Purpose

6. This report consolidates and documents preliminary research and development efforts on Army access/egress systems or concepts. These systems will support assault and follow-up phases of tactical river crossing operations.

Scope

7. Eight separate studies designed to address major requirements of the LOA for a tactical bridge access/egress system were consolidated into one report. Each of the studies was described previously either in a WES Memorandum for Record, a draft report, or a draft user's manual; this report summarizes the test results and documents the work in

chronological order. Each in-house report is presented as one of the appendices of this report.

LOA Requirements

8. The major requirements stated in the LOA for a tactical bridge access/egress system are summarized below:

- a. The assault vehicle egress role must allow swimming and fording combat vehicles to exit streams that have slopes within their normal climbing capabilities (maximum 25 percent). The egress points must be capable of withstanding 25 passes by vehicles up to and including Military Load Class (MLC) 60. The system will enable one squad of an Engineer Combat Company, using current organic equipment, to simultaneously install two egress points, 5 m wide and 15 to 20 m long, within 15 min after arriving at the exit bank.
- b. The bridge equipment access role must provide access lanes for use by gap crossing equipment to reach bridge launch sites. The access lanes must be capable of withstanding 50 passes by vehicles up to and including MLC 25. The system will enable 10 people from the Engineer Assault Float Bridge Company (ribbon), using current organic equipment, to install single lanes, 4 m wide, at the rate of 100 to 125 m in 30 min.
- c. The bridge traffic access/egress role must provide roadways capable of withstanding 2000 to 3000 vehicle passes (10 percent rated at MLC 60). The system will enable one platoon of the Engineer Combat Company (Corps), using current organic equipment, to install single, 4-m lanes at the rate of 250 to 300 m in 45 min.

The complete objectives are presented in the LOA (Appendix A). The mission of a tactical bridge access/egress system was to provide trafficability for wheeled and tracked vehicles over soils and slopes normally impassable and to assist those vehicles in access/egress at river crossing sites. The system will consist of soil and bank reinforcement capable of being installed (Headquarters, Dept. of the Army, 1965 and 1966a; Depts. of the Army and Air Force, 1968) using personnel and equipment organic to engineer units.

PART II: PRELIMINARY TRAFFIC INVESTIGATIONS
CONDUCTED ON PREPARED TEST SECTIONS

General

9. Beginning in December 1977 and continuing through September 1978, six separate test section subgrades were prepared from either buckshot clay or concrete sand under an airplane hangar-type structure at the WES to provide the conditions necessary for accurately controlled comparative traffic tests. The results of each test are summarized below, following the chronological test sequence, so that the impact of test results on subsequent tests is more apparent. Table 1 summarizes the test items, the sequence and results of measurements, and observations.

10. The first test subgrade was buckshot clay prepared at 0.5 California Bearing Ratio (CBR) strength. This strength was the lower limit of soil strength expected to support the LOA traffic on available depot surfacing. Since this subgrade strength did not support the required LOA tank traffic with any available surfacing mats and because the development of new surfacing capable of supporting the required traffic on less than a 2 CBR would be cost prohibitive, a 1 to 2 CBR subgrade strength was agreed upon (Harris, 1978) for further tests on prepared clay subgrades. Also in this letter (Harris, 1978), the M51 dump truck or the M54 cargo truck and the M48A1 tank were approved as primary test vehicles.

11. The LOA traffic requirement was met by both the M8A1 (Headquarters, Dept. of the Army, 1973; Tucker, 1968; Garrett, 1959) and M19 (Headquarters, Dept. of the Army, 1968 and 1973) landing mats in various placement configurations (Green and Ellison, 1969) with and without T17 membrane (Headquarters, Dept. of the Army, 1966b) on fat clay subgrades with minimum strengths of 1.2 CBR. For a subgrade less than 1.2 CBR, the M8A1 sustained only 150 truck passes, and the M19 sustained 2700 truck passes and 56 of the required 300 tank passes. Results of traffic attempts on unsurfaced and membrane-surfaced test sections are also

summarized in Table 1. Under ideal conditions, the square-foot-per man-hour-placement* rates of M19 and M8A1 landing mats achieve from 19 to 100 percent of the LOA required rates; however, the LOA rate was met for only one LOA role application. Recommended current usage of inventory hardware and a comparison of placement rates are presented in Part V.

12. Sand confinement grids with and without membrane underlay were also investigated for access/egress application. To investigate the potential application of off-the-shelf sand confinement grids, laboratory strength and deflection and prepared test section traffic tests were conducted using paper and aluminum grids and fiberglass catwalk-type panels.

13. The sand confinement tests indicated that all products and various test configurations with membrane will not sustain the LOA required traffic even after the tire pressure was decreased from 70 to 35 psi and the gross weight was decreased from 40,000 to 20,000 lb. The paper and aluminum grid lost all usefulness in confining sand after about 200 and 1,000 passes, respectively. The membrane underlay offered only slight benefit, if any. Similar performance of sand-filled grids was observed by Webster and Watkins (1977), Webster and Alford (1978), and Webster (1979) where little compaction was used in sand placement. However, it was observed in the tests by Webster that an unspecified amount of sand compaction and a surfacing of 2 to 3 in. of crushed stone or about 1 in. of a sand-asphalt surfacing within the top inch of the grid caused greatly enhanced trafficability. The sand compaction, addition of top surfacing, and/or required cure times as studied by Webster are prohibitive when considering the time requirements of the LOA.

Initial Traffic Tests on M8A1 and M19 Landing Mats

14. The initial tests were conducted using M8A1 and M19 landing mats (Headquarters, Dept. of the Army, 1968 and 1973) on buckshot clay

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

subgrade with a CBR strength of 0.5. A soil strength this low was difficult to work with because it would not adequately support construction equipment required to grade and slope the subgrade.

15. The M8A1 mat sustained only 150 passes of the M54 truck before it was considered a hindrance to vehicle maneuverability. The subgrade was forced through joints in the mat, creating traction problems in addition to being pumped to the edges of and above the mat surface, creating a bathtub effect. In the field, this bathtub effect would be a greater hindrance and the cause of surfacing failure in high rainfall areas. The M8A1 mat was reusable after the traffic tests.

16. The M19 mat sustained 2700 truck passes and 56 tank passes before the undercarriage of the tank began dragging on the mat. Connectors broke on six panels; the other panels were reusable. Some subgrade material was forced through the M19 mat joints, causing traction problems. Both the truck and tank traffic resulted in subgrade material being pumped to the side of the mat, creating a bathtub effect. The test details are presented in a WES Memorandum for Record included as Appendix B; test results are summarized in Table 1.

Tests of M8A1 Mats with and Without M8A1 Runners

17. Results of the first traffic test indicated that a CBR greater than 0.5 was required for comparative traffic data and future tests would be on a subgrade with a CBR strength between 1 and 2. A letter (Harris, 1978) from MERADCOM formally approved this subgrade strength.

18. All M8A1 test items in the second test section sustained the required 3000 passes of mixed truck and tank traffic. The mats suffered only minor damage (a few cracked and broken connector hooks); all the mats were still serviceable and reusable. The mats with welded runners maintained a smoother riding surface, but panels were in better condition for reuse from the section where the runners were not welded. A summary of the test results is presented in Table 1.

19. Excessive and undesirable subgrade material was forced

through the mat joints in all sections. Details and results of the tests on the M8A1 mat with and without M8A1 runners were described in a WES Memorandum for Record, included in this report as Appendix C. Photographs contained in Appendix C also show the bathtub effect that occurs as the surfacing system is forced into the subgrade after as few as 200 passes of the M54 truck.

M19 Mat Tests in Various Laying Patterns

20. Three placement patterns of the M19 mat were tested in a 1.3 CBR subgrade in the third test section. The panels in all placement patterns sustained the required passes of traffic and were in good condition for reuse. A summary of the test results is presented in Table 1.

21. Excessive subgrade was extruded onto the mat surface at the joints, indicating a need for a membrane underlay. For the traffic test on the normal lay pattern (Item 3), there was negligible downward and lateral movement of the mat. The distance of the subgrade above the mat was a maximum of 1.75 in. after the required 3000 passes of mixed truck and tank traffic in Item 1. Lateral movement due to the traffic and transverse slope built into the test section caused a maximum lateral movement of 4.5 in. in Item 1. The mats in the standard placement pattern (Green and Ellison, 1969) also maintained the smoothest surface and were recommended for further testing. Details and results of the tests on the M19 mat were described in a WES Memorandum for Record included in this report as Appendix D.

Tests on M8A1 and M19 Landing Mats with and Without T17 Membrane

22. The required mixed truck and tank traffic was performed on the M8A1 and M19 landing mats each with and without T17 membrane underlay in the fourth test section. The test results are summarized in Table 1; details of the tests and results were presented in a WES Memorandum for Record, included in this report as Appendix E. All items sustained the required 3000 passes of mixed truck and tank traffic; the

membrane proved effective in preventing extrusion of subgrade material through joints in the mat.

23. After the required traffic, the M8A1 mat was still serviceable but not suitable for reuse due to traffic damage (about half of the panels contained breaks). The M8A1 mat punched one hole in the T17 membrane underlay. The M19 mat was reusable after the required traffic and did not damage the T17 membrane underlay.

Evaluation of Paper and Aluminum Grids

24. The tactical access/egress system optimization required by the LOA necessitates investigation of potential alternate surfacing systems for sand that would be encountered in varying amounts in some river crossings. Because most granular materials have great strength when adequately confined, various sand-confining grids were subjected to traffic with and without a membrane underlay. The results of traffic tests in the fifth test section with reduced gross loads and lower tire pressures are summarized in Table 2. The details and results of laboratory tests and prepared-traffic test sections were documented in a WES Memorandum for Record, included as Appendix F.

25. The paper grid, impregnated with 9 percent phenolic resin to retard or prevent water absorption, tested with and without membrane, added some strength to the sand but not enough to be considered for extensive testing. Test results of this study and Webster (1979) indicated the 6-in. hexagon cell, 6 and 8 in. deep with surfacing, should be further tested for potential access/egress applications.

Evaluation of Borden and IKG Fiberglass Panels for Sand Confinement

26. Sand-confining fiberglass panels manufactured by Borden and IKG industries were trafficked with and without membrane in the sixth test section with reduced gross loads and tire pressures. The traffic test results are summarized in Table 3, and detailed test parameters and results of laboratory tests and traffic on prepared test sections were

documented in a WES Memorandum for Record, included in this report as Appendix G.

27. Traffic tests indicated that the fiberglass panels were damaged but the panels did not fail while sustaining traffic on both sand and clay subgrade; the traffic was stopped, however, either because of the lateral movement of panels from the traffic path or because the rut depth became excessive (vehicle undercarriage would drag). Lateral movement resulted from the panels working out of the sand or clay subgrade. The addition of weights along the edges of the panels was successful in holding the panels in place but tended to force displaced subgrade material to the middle of the wheel paths. The membrane did not appear to provide any significant improvement in the performance of the panels on either sand or clay subgrades.

28. The fiberglass panels increased the trafficability of the subgrade severalfold and indicated potential for access/egress applications. Design improvements recommended for the fiberglass panels included integral side connectors and a method of anchoring the panels in both sand and clay subgrades.

PART III: PRELIMINARY TESTS CONDUCTED ON PREPARED
SLOPES AND STREAM EGRESS LOCATIONS

29. In July 1978, traffic tests of military inventory items for effectiveness in riverine egress were begun on the WES reservation. Slope-climbing tests were conducted on a road cut (upland area) graded to a 25 percent slope; egress tests were also conducted on a 25 percent slope into Brown Lake. The tests were conducted on bare slopes, on slopes covered with T17 membrane, and M19 and M8A1 mat-surfaced slopes both wet and dry. The slope-climbing tests conducted in the upland area also required the vehicles to track through a wet clay at the toe of the slope. Drawbar pull tests were conducted with the M113 armored personnel carrier (APC) on T17 membrane stretched and anchored on level ground. A detailed description of the test items, both written and photographic, and the test results were included in a WES report, a draft of which is included in this report as Appendix H.

30. Summaries of the slope-climbing and lake egress tests are presented in Tables 4 and 5, respectively. The data showed that the T17 membrane, M19 mat, and M8A1 mat, when normally placed, will not provide adequate traction to support significant traffic on a 25 percent slope, wet or dry. The conclusions from Appendix H are reproduced below for the convenience of the reader:

- a. Tests with T17 membrane-covered slopes (25 percent or less) in upland areas and adjacent to a lake indicate that the membrane must be anchored extremely well on the slope and that the membrane itself does not necessarily assure traction at the toe of the slope at the water-soil interface. When wet, the membrane becomes relatively slick but still produces a sufficient traction surface for vehicle passage, provided the vehicle can negotiate the slope.
- b. Tests on mat-surfaced slopes (M8A1 or M19) indicate the same problems that were encountered in the membrane tests. When the mat was moved totally underwater, the vehicle negotiated the slopes, sometimes easily and other times marginally, depending on the mat configuration and the presence of any points on the mat for the vehicle to gain sufficient traction to climb the slope. The vehicles negotiated the mat-covered slopes rather easily, wet

or dry, when sufficient traction was obtained to climb the slope.

- c. Placement times of 15 min were not achieved. In fact, placement of the membrane or mat on riverbanks or slopes by any of the means used in the tests requires at least twice the time stated in the LOA. Also, engineer equipment must be available for anchor placement, mat placement upside down on the slope, and mat or membrane anchorage underwater.
- d. Membrane placed in lake bottoms underwater must be placed so that allowances are made for the membrane movement to conform to vehicle ruts in the soft lake bottom mud and the edges are anchored to the lake bottom to prevent entanglement in vehicle running gear. Cables attached to sandbags that were used to anchor the mat to the lake bottom in the tests reported herein became exposed with vehicle traffic and were easily entangled in the vehicle traction elements.
- e. The M113 APC was able to exit the lake at an unimproved soil ramp where the slope was less than 15 percent. The slope that represents its limiting capability is unknown.

PART IV: USE OF DEPOT HARDWARE FOR
ACCESS/EGRESS APPLICATION

31. A description of the installation and serviceability of inventory depot items, T17 membrane and M19 and M8A1 aircraft landing mats, and methods of deployment in the investigations reported in Appendices B through E and H is presented in Appendix I. Packaging of the inventory and pertinent ancillary items and placement times are presented so that Appendix I will function as a field manual for deployment of inventory items as access/egress hardware. A summary of Appendix I is reproduced below.

- a. Army inventory items that had potential to be used as access/egress surfacing were tested. These items consisted of T17 membrane, M19 landing mat, and M8A1 landing mat.
- b. Tests have indicated that the T17 membrane alone will not meet any of the bridge access/egress roles; however, it may be used as a waterproofing medium under a surfacing material to better accomplish the bridge equipment access role and/or the bridge traffic access/egress role. The M19 mat will support all the traffic required by the Letter of Agreement (LOA) but does not meet installation rates in the assault vehicle egress role and the bridge equipment access role and will not provide sufficient traction when wet and muddy as required in the egress role. The M8A1 mat placed either normally or inverted will support all of the required traffic of the LOA. Inverted, the surface will provide adequate traction for the M113 APC to egress a stream. The M8A1 mat will not meet any of the installation rates in any of the LOA roles.
- c. None of the inventory items described herein totally satisfies the requirements in the LOA for a tactical bridge access/egress surfacing. However, the M8A1 landing mat installed in the inverted position can serve as an emergency surfacing in the interim period while a surfacing system is being developed.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Recommended Current Usage of Inventory Items for General Access/Egress Application

32. A tabulation of the access/egress roles and the LOA time requirements for placement are presented in Table 6 with the recommended current usage of inventory hardware. This tabulation is a general summary of results from the preliminary investigations. It is intended to aid field engineers in selecting depot hardware for interim usage until an access/egress surfacing system is fully developed.

Conclusions and Future Research and Development Recommendations Based on Traffic Tests Conducted on Existing Hardware and Prototype Material

33. The following observations are warranted based on traffic tests conducted on existing hardware and prototype material:

- a. Initial traffic tests on M8A1 and M19 mats. A 0.5 CBR subgrade was determined to be below the lower limit of soil strength that can support the LOA traffic on available depot surfacing.
- b. Tests on the M8A1 mat with and without M8A1 runners. The M8A1 mat with and without runners on 1.3 CBR subgrade sustained the required LOA traffic (3000 passes) and remained serviceable and reusable.
- c. A bathtub effect, created by the mat being forced into the subgrade by the traffic, would be detrimental in areas of high precipitation. Excessive and undesirable subgrade material was forced through the mat joints in all sections.
- d. M19 mat tests in various laying patterns. The M19 panels in the three placement patterns tested sustained the required passes of traffic on 1.3 CBR subgrade and were in good condition for reuse.
- e. The standard placement pattern maintained the smoothest surface and was recommended for future testing.
- f. Excessive subgrade was extruded onto the mat surface at the joints; the bathtub effect was less than that for the M8A1 mat.
- g. Tests on M8A1 and M19 landing mats with and without T17

membrane. The M8A1 and M19 mats sustained the required LOA traffic with the T17 membrane underlay without extruded subgrade material interfering with traction of vehicles.

- h. The M19 panels were reusable after the tests; the M8A1 mats were not.
- i. Evaluation of paper and aluminum grids for bridge access/egress application. The aluminum 6-in. hexagon cell, 8-in.-depth grid with and without membrane provided more strength in the sand subgrade than did the other grids and membrane combinations. This grid with and without membrane sustained 1000 passes of the M54 truck and was still trafficable. The rut depth of this grid with and without membrane after 1000 passes was only 4.6 and 4.9 in. The rut depths for the unsurfaced sand and other grid/membrane combinations used for reinforcement were much greater. However, except for the aluminum 6-in. hexagon cell, 6-in.-depth grid, the other materials had failed at 100 passes or less. Although the rut depth for the aluminum 6-in. hexagon cell, 6-in.-depth grid with and without membrane after 1000 passes of traffic was 7.2 and 7.7 in., these materials remained trafficable.
- j. The paper grid, impregnated with 9 percent phenolic resin, with and without membrane and the aluminum 6-in. hexagon cell, 4-in.-depth grid with and without membrane provided some added strength to the sand subgrade. However, since these materials failed during this investigation and were considered ineffective in adequately confining the sand, no further tests are recommended.
- k. It is recommended that traffic tests with the M54 cargo truck with highway loading conditions (40,000-lb gross weight) and tires (inflated to 70 psi) be considered on aluminum 6-in. hexagon cells, 6- and 8-in.-depth grids both with and without Kevlar membrane placed on a loose sand subgrade and a weak (1 to 2 CBR) clay subgrade with the cells filled with loose sand in order to fully optimize the cell sizes and depths of these materials, when sand filled without compaction and without benefit of any additional surfacing.
- l. The Borden and IKG panels, if given future consideration in the access/egress programs, should be developed to include integral side connectors.
- m. A method of anchoring the Borden and IKG panels would be necessary if these panels are to be considered in future access/egress studies.
- n. The Borden and IKG panels, if redesigned with improvements suggested, should be tested both on a loose sand

and a weak (1.2 to 2.0 CBR) clay subgrade with the M54 cargo truck with gross load of 40,000 lb and tires inflated to 70 psi.

Conclusions and Recommendations Based on
Slope Investigations Conducted with
Inventory Materials

34. The slope and streambank egress tests indicated the following conclusions and recommendations for future tests:

- a. Tests with T17 membrane-covered slopes (25 percent or less) in upland areas and areas adjacent to a lake indicate that the membrane must be anchored extremely well on the slope and that the membrane itself does not necessarily assure traction at the toe of the slope at the water-soil interface. When wet, the membrane becomes relatively slick but still produces a sufficient traction surface for vehicle passage, provided the underwater slope does not degrade to a steeper slope.
- b. Tests on mat-surfaced slopes (M8A1 or M19) indicate the same problems encountered in the membrane tests. When the mat was moved totally underwater, the vehicle negotiated the slopes, sometimes easily and other times marginally, depending on mat configuration and the presence of any points on the mat for the vehicle to gain sufficient traction to climb up the slope. The vehicle negotiated the mat-surfaced slope rather easily, wet or dry, when sufficient traction was obtained to climb up the slope.
- c. An installation time of 15 min for an egress point 5 m wide and 15 to 20 m long is not realistic for hard labor placement of membrane or mat placement on riverbanks or slopes. Also, engineer equipment must be available for anchor placement, mat placement in an inverted condition on the slope, and mat placement or membrane anchorage underwater.
- d. Membrane placed underwater in lake bottoms must be placed so that allowances are made for membrane movement to conform to vehicle ruts in soft streambed sediments. The edges must be anchored to prevent entanglement in vehicle running gear. Cables attached to sandbags used to anchor the mat to the lake bottom in the tests reported herein became exposed with vehicle traffic and were easily entangled in the vehicle traction elements.
- e. Tests should be conducted with experimental traction devices underwater to determine a maximum underwater slope

for the traction device to assure vehicle slope passage.

- f. Tests should be conducted on slopes of other soil types, especially clays, to determine any detrimental effects of clay on vehicle performance. Water egress tests should be conducted at various slopes less than 25 percent to determine the limit of egress on unimproved slopes. (This is presently estimated to be less than a 15 percent slope.) The use of an anchor and winch to assist a tracked vehicle to exit a stream on a 25 percent slope should be evaluated (even though no present combat vehicle has the capability). There are circumstances where a bulldozer or universal engineer tractor might be able to ford a stream and get closer to the bank to use its winch if either piece of equipment were available.
- g. Other available depot items of possible relevance to these tests in terms of bank surfacing or stabilization should be tested under field conditions.
- h. A mat, similar to the inverted M8A1 with integral traction devices, should be designed and tested for the access/egress surfacing.

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Table 1
Summary of Preliminary Tests for Tactical Bridge Access/Egress Systems

Mat Type	Prepared Subgrade Material	CBR ¹	Test Vehicle ²	Lay Pattern	No. of Passes ³	Maximum Deformation in Item, in. Perpendicular to Traffic	Apparent Embedment of Mat into Subgrade, in.	Test Comments
Traffic Tests on M19 and M8A1 Landing Mat (Appendix B)								
M19 (Item 1)	Buckshot clay (24-in. thickness)	0.5	M54	Brickwork	0-32	--	0.5	Little movement; some subgrade material forced through joints
			M54		33-70	--	0.75	No visible damage
			M54		71-150	--	--	No visible damage
			M54		151-2700	1.7	4.0	No visible damage
			M48A1		2701-2702	--	6.0	Mat sprang up 3 in
			M48A1		2703-2756	7.8	20.0	Connectors broke on 6 panels; other panels reusable. Tank dragging undercarriage (~15 in.)
Evaluation of M8A1 Mat for Bridge Access/Egress Surfacing (Appendix C)								
M8A1 (Item 2)	Buckshot clay (24-in. thickness)	0.5	M54	One panel wide	0-32	--	6.0	Bow wave forced subgrade material through joints and to side
			M54		33-70	--	20.0	
			M54		71-150	17.6	16.6	Truck immobilized--slipped off mat. Traffic discontinued. Mat was undamaged and reusable

Evaluation of M8A1 Mat for Bridge Access/Egress Surfacing (Appendix C)

M8A1 (Item 1)	Buckshot clay (24-in. thickness)	1.2	M54	One panel wide (no runners)	0-200	2.0	1.5	3.0
			M54		201-1000	--	--	8.0
			M54		1001-1800	3.0	3.0	14.0
			M48A1		1801-1830	--	--	--
			M48A1		1831-2000	3.5	3.0	--

(Continued)

1 Item refers to description of test subgrade and surfacing system in appropriate appendix.

2 The second CBR value shown during a traffic sequence reflects the measured change in subgrade strength due to test conditions.

3 The test vehicle for a sequence of passes was an M54 cargo truck (40,000 lb gross) or an M51 dump truck (40,000 lb gross) and an M48A1 tank (106,000 lb gross).

4 The sequence of traffic was 2700 truck and 300 tank passes for the initial tests described in Appendix B; the sequence of traffic for all other tests summarized in this table was as follows: truck 0-1800, 2001-2450, and 2501-2950 passes, tank 1801-2000, 2451-2500, and 2951-3000 passes.

(Sheet 1 of 4)

Table 1 (Continued)

Mat Type	Prepared Subgrade Material	CBR	Test Vehicle	Lay Pattern	No. of Passes	Maximum Deformation in Item, in.		Apparent Embedment of Mat into Subgrade, in.	Test Comments
						Perpendicular to Traffic	Parallel to Traffic		
Evaluation of M8A1 Mat for Bridge Access/Egress Surfacing (Appendix C) (Continued)									
M8A1 (Item 1) (Cont'd)	Buckshot clay (24-in. thickness) (Cont'd)	1.4	M54	One panel (no runners) (Cont'd)	2001-2450	--	--	--	Mat ends off subgrade 2-1/2 in.
			M48A1		2451-2500	--	--	--	Mat ends off subgrade 4 in.
			M54 & M48A1		2501-3000	3.5	4.0	--	End connector hooks broken off 3 panels, 3 others cracked, but panels were reusable; 1.25-in. permanent set
						--	--	--	Little permanent set
						--	--	--	Mats seated 1 in. and increased only slightly to 1800 passes
						--	--	--	Mat sprang off embedded runners 2 in.
		1.4	M48A1		1801-2000	2.0	2.0	--	Mat sprang 2 in. off runners; two 1/4-in. breaks at base of connector hooks. Mats were reusable
			M54 & M48A1		2001-3000	2.5	3.0	--	More than half the mat embedment occurred in 200 passes
						--	--	--	Runners rebounded 2 in. above subgrade
M8A1 (Item 3)	Buckshot clay (24-in. thickness)	1.2	M54	One panel wide welded to M8A1 runners	0-200	1.5	1.5	--	Two panels had one weld each broken. Panels were in good condition for reuse
			M54		201-1800	1.5	2.0	--	Standard lay pattern rotated 90°
		1.4	M48A1		1801-2000	2.0	2.0	--	A 3-in. transverse slope and traffic caused lateral movement of 4.5 in.
			M54 & M48A1		2001-3000	2.5	2.5	--	Lateral movement corrected prior to tank traffic. No lateral movement due to embedment. Subgrade material was extruded through mat joints. No damage to mat
Traffic Tests on M19 Landing Mat (Appendix D)									
M19 (Item 1)	Buckshot clay (24-in. thickness)	1.2	M54	Reinforced major female sections, perimeter	0-200	--	--	--	
			M54	Reinforced perimeter	201-1800	1.00	0.75	--	
			M48A1	Reinforced perimeter and traffic	1801-2000	1.25	1.0	1.5	
		1.4	M54 & M48A1	Reinforced perimeter	2001-3000	1.75	1.0	1.75	

(Continued)

(Sheet 2 of 4)

Table 1 (Continued)

Mat Type	Prepared Subgrade Material	CBR	Test Vehicle	Lay Pattern	No. of Passes	Maximum Deformation in Item, in.		Apparent Embedment of Mat into Subgrade, in.	Test Comments
						Perpendicular to Traffic	Parallel to Traffic		
Traffic Tests on M19 Landing Mat (Appendix D) (Continued)									
M19 (Item 2)	Buckshot clay (24-in. thickness)	1.2	M54	Brickwork, overlap joints perpendicular to direction of traffic and continuous across width of item	0-200	--	--	--	1.0 in. of lateral movement
			M54		201-1800	1.0	1.0	--	3.0 in. of lateral movement
			M48A1		1801-2000	1.75	1.0	1.5	Lateral movement corrected prior to tank traffic. Subgrade material was extruded through mat joints
		1.3	M54 & M48A1		2001-3000	1.75	1.25	--	
M19 (Item 3)	Buckshot clay (24-in. thickness)	1.2	M54	Brickwork, male-female joints parallel to direction of traffic & continuous along length of item	0-200	--	--	--	Less downward mat movement than in items 1 and 2. No lateral movement
			M54		201-1800	0.75	0.75	--	Subgrade material was extruded through mat joints
			M48A1		1801-2000	1.25	1.0	--	
		1.3	M54 & M48A1		2001-3000	1.50	1.25	--	
None	Buckshot clay (24-in. thickness)	1.3	M48A1	Unsurfaced test section	0-1	3.0	3.0	NA	Tank produced 3-in. ruts in 2 passes
					2-9	11.0	11.0	NA	Undercarriage of tank touching subgrade (~15 in.)
					10-50	--	--	NA	Undercarriage dragging enough to stop test. Distance from top of subgrade to bottom of rut about 30 in.
Traffic Tests on M8A1 and M19 Landing Mats with and Without T17 Membrane Underlay (Appendix E)									
M8A1 (Item 1)	Buckshot clay (24-in. thickness)	1.2	M51	Brickwork, 1 and 1/2 panels wide, adjacent sides connected by bayonets & slots, ends joined by connector bars and bending, coverplate tabs down (No underlayment)	0-200	2.0	2.75	--	Subgrade extruded through mat joint
			M51		201-1800	2.7	3.0	--	Mat sprang off subgrade 3 to 4-1/2 in. in 1800 passes
			M48A1		1801-2000	3.5	3.0	--	Mat sprang 7-1/2 in. off subgrade
		1.6	M51 & M48A1		2001-3000	3.75	3.5	--	10 of 24 panels had breaks (summary of damage on Incl 18 of Appendix E). Panels unsuitable for reuse

(Continued)

(Sheet 3 of 4)

Table 1 (Concluded)

Mat Type	Prepared Subgrade Material	CBR	Test Vehicle	Lay Pattern	No. of Passes	Maximum Deformation in Item, in. Perpendicular to Traffic	Parallel to Traffic	Apparent Embedment of Mat into Subgrade, in.	Test Comments
Traffic Tests on M8A1 and M19 Landing Mats with and without T17 Membrane Underlay (Appendix E) (Continued)									
M8A1 (Item 2)	Buckshot clay (24-in. thickness)	1.2	M51	Brickwork, same lay pattern as item 1 but used T17 membrane underlay	0-200	1.5	2.2	--	Mat sprang 2 in. off subgrade
			M51		201-1800	2.25	1.75	--	Mat sprang 3 in. off subgrade
			M48A1		1801-2000	2.75	2.00	--	Mat sprang 6-1/2 in. off subgrade
		1.5	M51 & M48A1		2001-3000	2.60	2.00	--	Mat still serviceable; 13 of 24 panels contained breaks; permanent set would hinder reuse; one punctured hole was observed in T17 membrane
Traffic Tests on M8A1 and M19 Landing Mats with and without T17 Membrane Underlay (Appendix E)									
M19 (Item 3)	Buckshot clay (24-in. thickness)	1.2	M51	Brickwork, male-female joints parallel to direction of traffic and continuous along length of item, with T17 underlay	0-200	0.75	0.80	--	Small hinge movement at connectors
			M51		201-1800	1.5	1.25	--	
			M48A1		1801-2000	1.6	1.5	--	No significant change in mat
		1.5	M51 & M48A1		2001-3000	1.6	1.6	--	Mat in good condition; no holes in T17 membrane. No subgrade extruded through mat joints
M19 (Item 4)	Buckshot clay (24-in. thickness)	1.2	M51	Brickwork, male-female joints parallel to direction of traffic and continuous along length of item, without T17 underlay	0-200	0.5	0.75	--	Small hinge movements at connectors
			M54		201-1800	0.75	1.00	--	
			M48A1		1800-2000	1.00	1.25	--	No significant change in mat
		1.5	M51 & M48A1		2001-3000	1.20	1.50	--	Mat in good condition. No subgrade extruded through joints on 1.2 CBR subgrade without T17
Unsurfaced subgrade	Buckshot clay (24-in. thickness)	1.5	M51	NA	1	14.5	--	--	Test conducted on items 1 and 2 above with surfacing removed. After 10 passes, rear springs were dragging and test was discontinued
					10	19.0	--	--	
Membrane surfaced subgrade	Buckshot clay (24-in. thickness)	1.5	M51	NA	1	6.25	--	--	Test conducted on items 3 and 4 above with T17 membrane only for surfacing
					10	14.25	--	--	After 10 passes, rear springs on truck dragging and test discontinued

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(Sheet 4 of 4)

Table 2
Summary of Traffic Tests on Sand-Confining Paper and Aluminum Grids

Materials	Grid Size	Grid Depth	Weight (Weight/Area)	Panel Size	Cost	With/ Without Membrane	Number of Passes	Rot Depth in.	Comments
None	--	--	--	--	--	W/O	0*	>12	Truck became immobilized after going about 20 ft in loose sand
None	--	--	--	--	--	W/O	10 50	7-8 11-12	Truck undercarriage touched sand subgrade after 50 passes
Paper honeycomb	6 in.	6 in.	57 lb (0.29 lb/sq ft)	24 x 8 ft	\$0.61/sq ft	W/O W W/O W	10 10 200 200	7.4 6.8 9.0 10.8	Paper grid after 200 passes had lost all usefulness in confining the sand
Aluminum honeycomb	6 in.	4 in.	55 lb (0.34 lb/sq ft)	20 x 8 ft	\$1.38/sq ft	W/O W W/O W/O	10 10 500 500 1000	5.8 4.4 7.4 7.3 6.7	Grid with membrane had failed after 500 passes and was no longer effective in confining the sand. Grid without membrane had failed after 1000 passes and was no longer effective in confining the sand
Aluminum honeycomb	6 in.	6 in.	86 lb (0.53 lb/sq ft)	20 x 8 ft	\$2.06/sq ft	W/O W W/O W	10 10 1000 1000	4.1 3.8 7.7 7.2	Slight benefit from membrane
Aluminum honeycomb	6 in.	8 in.	127 lb (0.79 lb/sq ft)	20 x 8 ft	\$2.75/sq ft	W/O W W/O W	10 10 1000 1000	3.6 3.7 4.9 4.6	Slight benefit from membrane
Neoprene Kevlar membrane**	--	--	67 lb (1.7 oz/sq ft)	15 x 40 ft	\$2.58/sq ft	--	--	--	--

* Test vehicle was an M54 5-ton cargo truck with 40,000-lb gross weight and tires inflated to 70 psi. Other traffic passes shown on this summary were made with an M54 5-ton car truck with 20,000-lb gross weight and tires inflated to 35 psi.

** Material thickness, 0.013 in.

Table 3
Summary of Traffic Tests on Sand-Confining Borden and IKG Fiberglass Panels

Materials	Grid Size	Grid Depth	Weight (Weight/Area)	Panel Size	Cost	With/Without Membrane	Number of Passes*	Rut Depth in.	Comments
None	--	--	--	--	--	W/O	0	12	Truck became immobilized after going about 20 ft in loose sand
None	--	--	--	--	--	W/O	10 50	7-8 11-12	Undercarriage of truck was touching sand sub-grade after 50 passes
IKG fiberglass	7/8 x 5-5/8 in.	1 in.	97 lb (2.5 lb/sq ft)	3 x 13 ft	\$8.35/sq ft	W/O	10	2.8	After 700 passes, material worked out of sand;
						W	10	2.3	anchor weight added; at
						W/O	1000	4.5	1000 passes rut depth as
						W	1000	3.4	shown at left
Borden fiberglass	1 x 4 in.	1 in.	130 lb (2.7 lb/sq ft)	4 x 12 ft	\$6.71/sq ft	W/O	10	2.2	Material worked out of
						W	10	2.0	sand after 200 passes;
						W/O	1000	2.0	anchor weights added; and after 1000 additional passes, material worked out of sand
Neoprene Kevlar membrane**	--	--	67 lb (1.8 oz/sq ft)	15 x 40 ft	\$2.58/sq ft	--	--	--	--

* Test vehicle was an M54 5-ton cargo truck with 40,000-lb gross weight and tires inflated to 70 psi. Other traffic passes shown in this summary were made with an M54 5-ton cargo truck with 20,000-lb gross weight and tires inflated to 35 psi.

** Material thickness, 0.013 in.

Table 4
Summary of Traffic Test on 25 Percent Slope (14 Degrees), Upland Area

Mat Type	Vehicle	Dry			Wet			Wet Clay**			Remarks
		Passes	Moved, in.	Maximum Mat	Passes	Moved, in.	Maximum Mat	Passes	Moved, in.	Maximum Mat	
Unsurfaced soil (no mat)	M113	25	--(1)**	--	2	--	--	--	--	--	(1) Rut depth of 4-1/2 in. after traffic of three vehicles
	M54	25	--	--	0	--	--	--	--	--	
	M48A1	25	--	--	1	--	--	--	--	--	
M19 anchored	M113	25	1/8	3/8	25	3/8	1/8	25	1/8	0	(2) Plus three attempts
	M54	25	6-3/4	1-1/2	25	1-1/2	0	0	0	0	
	M48A1	25	6-3/4	6-1/4	25	6-1/4	1-1/4	5(2)	1-1/4	1-1/4	
M19 unanchored	M113	25	3-7/8	7-1/4	25	7-1/4	--	--	--	--	
	M54	25	19-5/8	4	25	4	--	--	--	--	
	M48A1	25	16-1/4	8-1/8	25	8-1/8	--	--	--	--	
M8A1 anchored	M113	25	3/8	1/2	25	1/2	--	--	--	--	
	M54	25	3/4	1-3/8	25	1-3/8	--	--	--	--	
	M8A1	25	1/2	1-1/8	25	1-1/8	--	--	--	--	
M8A1 unanchored	M113	25	3/8	1/4	25	1/4	5/8	25(3)	5/8	5/8	(3) Slid off of mat edge on last pass (4) Attempted three passes (5) Plus three attempts (6) Slight
	M54	25	1/4	1	25	1	1/8	0(4)	1/8	1/8	
	M48A1	25	1/2	5/8	25	5/8	--(6)	3(5)	--(6)	--(6)	
M8A1, inverted anchored	M113	--	--	--	--	--	--	25	5-1/2(7)	5-1/2(7)	Failed 1st attempt. Successful after tank traffic
	M54	--	--	--	--	--	--	0	--	--	
	M48A1	--	--	--	--	--	--	25	12-1/4(7)	12-1/4(7)	
T17 membrane anchored	M113	25	1-1/2	3(8)	25	3(8)	4(11)	4(11)	--	--	(7) Clay superwet (8) Caused 5-1/4- and 2-1/4-in. tears (9) Caused 1- and 1-1/2-in. tears (10) No change (11) Ten attempts with 20-ft start made four passes, membrane severely damaged (12) Membrane torn across entire width
	M54	25	3	3/8(9)	25	3/8(9)	0	0	2-1/2	2-1/2	
	M48A1	25	5	3-3/4(10)	25	3-3/4(10)	0	0	--(12)	--(12)	

* Tests required vehicles to track through wet clay at toe of slope.
** Numbers in parentheses refer to similarly numbered comments under the Remarks heading.

Table 5
Summary of Traffic Tests on T17 and M8A1 on 25 Percent Slope, Brown Lake*

Test	Cumulative Attempts	Cumulative Passes	Type Surfacing	Mat		Distance from Waters Edge to 1st mat, ** ft	Slope Condition	Remarks
				Surface Up/Down	End in Water, 1st			
1	1	1	T17	NA	NA	NA	Dry	Membrane anchorage inadequate, excess membrane fold needed to allow membrane to conform to ruts; membrane and sandbag ropes became entangled in left track, pulling membrane from slope
2	1	0	T17	NA	NA	NA	Dry	Membrane anchored better with 4-ft fold at water's edge; M113 could not pull out of lake. Small tear noted near waterline
	2	0	T17	NA	NA	NA	Dry	Membrane shredded in numerous places, immobilizing the M113 by damaging the bearings and shaft inside the left sprocket. The vehicle apparently cannot climb the membrane after it is wet from being pushed into the lake bottom
1	5	0	M8A1	Up	Hook	NA	Dry	Eleven runs of mat in water, five runs on slope. Insufficient traction for M113 to move up slope
2	2	1	M8A1	Down	Rolled	NA	Dry	Ten runs in water, six runs on slope; unanchored. M113 slowly exited up slope
	5	2		Down	Rolled	NA	Dry	Thirteen runs in water, three runs on slope; anchored. Halted when mat slipped completely into the water
	31	26		Down	Rolled	NA	Dry	After one pass, all mats pulled into water. After eight passes all mats pulled 18 in. underwater. Success of attempts seemed to be operator-dependent
1	15	15	M8A1	Down	Rolled	1.5	Wet	Anchor failed. Bank five runs of mat disconnected from 11 runs in lake. M8A1 was heavily damaged after 15 passes
	19	18		Down	Rolled	1.5	Wet	Anchor failed again before completing 25 passes
	28	25		Down	Rolled	2.0	Wet	Five runs only
4	5	0	M8A1	Up	Rolled	4.0	Wet	Five runs only
5	5	0	M8A1	Down	Hook	2.5	Wet	Five runs only. Two slow and three fast attempts
6	4	0	M8A1	Down	Hook	4.0	Wet	Slow and fast attempts
7	10	8	M8A1	Down	Hook	4.0	Wet	Two runs only. After two passes, mat 6 ft in water
8	11	9	M8A1	Up	Rolled	4.0	Dry	Two runs only. Poor control of vehicle. M8A1 mat provides only marginal assistance in egress

* All tests at Brown Lake were conducted with the M113 armored personnel carrier loaded to 22,865 lb gross. In the last test, the slope in and near the water had probably decreased because of traffic.

** Other mats were farther out in the water.

Table 6
Current Recommended Usage of Inventory Hardware
for Access/Egress Applications

Access/Egress Role	Inventory Item		
	M19	T17*	M8A1
<u>Assault</u>			
Structural adequacy**	Yes	No	Yes
Vehicle traction on 25 percent slope, dry	Yes	Yes	Yes
Vehicle traction on 25 percent slope, wet	Yes†	Yes†	Yes††
Climbing out of water	No	No	Yes††
Deployment time required (square feet per man-hour)	240	0.03‡	163
Special equipment	No	No	No
LOA time requirement (square feet per man-hour)	861	NA	861
<u>Bridging equipment access</u>			
Structural adequacy	Yes	No	Yes
Deployment time required (square feet per man-hour)	573	20,000‡‡	361
Special equipment	No	No	No
LOA time requirement (square feet per man-hour)	1076	NA	1076
<u>Bridge traffic access/egress</u>			
Structural adequacy	Yes	No	Yes
Deployment time required (square feet per man-hour)	573	20,000‡‡	361
Special equipment	No	No	No
LOA time requirement (square feet per man-hour)	574	NA	574

* For use beneath M19 or M8A1.

** 1.3 CBR or better subgrade.

† But not through wet clay at toe of slope.

†† Yes, with mat inverted but marginal with wet clay or water at toe of slope.

‡ Deployment on slope requires trench, additional anchorage, and backfilling.

‡‡ Deployment time based on 5 men placing a 2000-sq-ft bundle of T17 membrane under ideal conditions in 1 min.

APPENDIX A

LETTER OF AGREEMENT (LOA) TACTICAL
BRIDGE ACCESS/EGRESS SYSTEM

24 July 1979



DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA 23061

ATCD-MC

24 July 1979

SUBJECT: Letter of Agreement (LOA) for a Tactical Bridge Access/Egress System, USATRADOC ACN 38653

SEE DISTRIBUTION

1. Reference AR 71-9.
2. Attached at inclosure 1 is the approved TRADOC/DARCOM Letter of Agreement for a Tactical Bridge Access/Egress System. The following information is applicable to this document:
 - a. System Designation: N/A
 - b. Materiel Developer: DARCOM
 - c. Combat Developer: USATRADOC
 - d. User Representative: USATRADOC
 - e. Trainer: USATRADOC
 - f. Logistician: USALEA
 - g. CARDS Reference Number: 0608A
 - h. Operational Test Responsibility: USATRADOC
 - i. USATRADOC Proponent Activity: USAES
3. DARCOM, in coordination with the USATRADOC proponent activity, will initiate preparation of the Outline Development Plan (ODP) IAW AR 71-9.

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ATCD-MC

24 July 1979

SUBJECT: Letter of Agreement for a Tactical Bridge Access/Egress
System, USATRADOC ACN 38653

4. Subject requirement document is forwarded to major Army commands,
other services and DOD agencies for harmonization and to all other
addressees for information.

FOR THE COMMANDER:



ROBERT W. LECKER
LTC, AGC
Assistant AG

1 Incl
as

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(see next page)

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1. NEED.

Improved enemy response time, target acquisition capability, range, and accuracy of enemy weapons indicate that in the 1980 time frame, concentrations of troops will be quickly detected, identified, located, and engaged. It is therefore essential that modern gap crossings systems, to include access and egress routes, are capable of being emplaced fast enough to allow mission essential traffic to cross before countermeasures are effectively applied. With the advent of modern and more rapidly emplaced bridging, the need to gain an equivalent capability to reach the gap with crossing equipment and to maintain subsequent traffic flow has become essential. Specific conditions that must be overcome are poor soil conditions or steep slopes at the near bank that limit access to both bridging equipment and amphibians; poor soil conditions or steep slopes at the exit bank that prevent tactical assault vehicles from exiting the stream at the most tactically advantageous locations; and poor soil conditions at points of congestion and heavy traffic areas such as bridge approaches and assembly areas which restrict or halt traffic flow. In view of the problem areas stated above, a Tactical Access/Egress System should be ready for fielding during FY 1984-1986.

2. OPERATIONAL CONCEPT.

a. The access/egress system will be employed primarily in the assault and follow-up phases of tactical river crossing operations. Components will be used by the Divisional Combat Engineer Company, the Engineer Assault Float Bridge Company (Ribbon) and the Engineer Combat Company (Corps) in the main battle area to aid crossing of swimming and fording vehicles; to enable bridge or raft transport vehicles to reach launch sites; and to provide trafficable roadways to and from bridges or raft loading points for assault and follow-up forces. The system concept supports the doctrine described in FM 100-5 and FM 90-13, i.e., to maximize the speed, surprise, and violence of the attack, broaden the choice of crossing sites, and enable combat support elements to keep pace with maneuver units. The need for a rapid means of overcoming water barriers for which access and egress are difficult, has been an item of interest to the Quadripartite Working Group for Bridging and Gap Crossing (QWG/BGC) since September 1974. ABCA interest in the Tactical Bridge Access/Egress System has been ongoing since a January 1978 QWG/Engineering meeting.

b. Mission Profile - see Annex A.

3. SYSTEM DESCRIPTION.

a. To overcome the threat, the access/egress system will use new technology or modifications and/or adaptations of standard surfacing and soil strengthening materials to meet the following goals:

(1) Assault Vehicle Egress Role. The system must allow swimming

and fording combat vehicles to exit streams that have slopes within their normal climbing capabilities (maximum 25%). The egress points must be capable of withstanding at least 25 passes by vehicles up to and including Military Load Class (MLC) 60. The system will enable one squad of an Engineer Combat Company, using current organic equipment, to simultaneously install two egress points five meters wide and 15-20 meters long within 15 minutes after arriving at the exit bank.

(2) Bridge Equipment Access Role. The system must provide access lanes for use by gap crossing equipment to reach bridge launch sites. The access lanes must be capable of withstanding at least 50 passes by vehicles up to and including MLC 25. The system will enable 10 people from the Engineer Assault Float Bridge Company (Ribbon), using current organic equipment, to install single lanes, four meters wide, at the rate of 100-125 meters in 30 minutes.

(3) Bridge Traffic Access/Egress Role. The system must provide roadways capable of withstanding 2000-3000 vehicle passes (10% rated at MLC 60). The system will enable one platoon of the Engineer Combat Company (Corps), using current organic equipment, to install single, four meter lanes at the rate of 250-300 meters in 45 minutes.

b. If possible, the goal of the Tactical Bridge Access/Egress System is to develop a single system that meets all three bridging access/egress roles.

c. The access/egress system will be composed of a combination of soil confinement grids, membranes, and surfacing materials. In determining the soil confinement grid, materials with various grid-size openings, depths, and material thicknesses will be investigated. Membranes and surfacing materials will be investigated to optimize the design required. In actual field employment, the soil strength at the individual site will be the determining factor as to whether one, a combination of two, or all three of the above materials will be required for the access/egress system.

d. The tactical bridge access/egress system must be sufficiently mobile to accompany the force supported (compatible with that of the tactical bridge equipment itself).

e. System safety criteria as required by Military Standard 882 and AR 385-16 apply to this system.

f. To enhance the survivability of the system and the using unit, the material must present a minimum visual signature. Desired features include camouflage painting, reduced heat retention, reduced radar reflectivity, etc.

g. Nuclear survivability is not required because the system is not critical to mission accomplishment in a nuclear conflict.

h. Chemical/biological protective measures will be considered as applicable to any hardware items developed for this system. To facilitate chemical agent decontamination, chemical agent resistant materials will be used to the maximum extent practicable in the development of this item. If practical, this item will be painted with chemical agent resistant paints to facilitate chemical agent decontamination.

i. Protection against electronic countermeasures and countermeasures (ECM/ECCM) does not apply to this system.

j. The system may be palletized or banded and will be transportable to and within the theater by highway, rail, marine and air transport. Suitable lifting and tie-down devices will be provided as required.

4. PROSPECTIVE OPERATIONAL EFFECTIVENESS.

The proposed system is expected to provide significant improvements in operational effectiveness of the bridge unit because equipment will be able to gain access to one or more selected crossing sites in minutes instead of hours. The combat engineers will be able to build access and egress roadways at both ends of a bridge at a rate of approximately four times faster than currently possible. The supported tactical elements will realize significant improvements when mission delays caused by water barriers are minimized, a wider choice of crossing sites are available, and swimming/fording vehicles are quickly provided several egress points along the exit bank. The proposed system is expected to provide significant reductions in the cost of time/resources in preparing access/egress routes, since it will be emplaced quickly by fewer people without the use of heavy earthmoving equipment.

5. SYSTEM DEVELOPMENT.

a. Operational Employment Plan. Commander, TRADOC with input from DARCOM, will conduct the necessary studies, war games and test and evaluation to define the operational concepts. Additionally, the following critical issue will be addressed in OT I:

Can the training requirements be met with the training concept?

b. Technical Development Plan. The technical risk for this development is estimated to be medium. Commander, DARCOM, will conduct those activities prescribed in pertinent command and materiel acquisition regulations and insure that the following critical issues are resolved before or during DT I:

(1) Determine if the system can withstand 25 passes by vehicles up to MLC 60 at exit bank egress points (Technical risk: Low).

(2) Determine if the system can provide traction for swimming/fording combat vehicles at exit bank egress points with slopes up to 25% (Technical risk: Medium).

(3) Determine if the system can provide access to bridge/raft launch sites capable of supporting 50 passes by vehicles up to MLC 25 (Technical risk: Low).

(4) Determine if, with minimal maintenance, the system can provide bridge access/egress routes that can withstand 2000-3000 passes by division/corps vehicles - 10% MLC 60 (Technical risk: Medium).

(5) Determine if the system can be installed in the required time during daylight and dark using only the equipment organic to the units identified in paragraph 3a (Technical risk: Medium).

(6) Determine if the success of the system is site independent (Technical risk: Medium).

(7) Determine if the system's individual components are effective for certain areas when used separately (Technical risk: Low).

(8) Determine if the system is overly dependent on any one of the individual components (Technical risk: Low).

(9) Determine if any excessive personnel hazards or equipment hazards are produced by installation, use, or retrieval of the system (Technical risk: Low).

(10) Determine if the system can be transported with vehicles organic to the units named in paragraph 3a (1)-(3), as well as general purpose cargo carrying vehicles (Technical risk: Low).

c. Logistical Support Plan. Commander, DARCOM, with input as required from TRADOC and LEA, will conduct those activities prescribed in pertinent command and materiel acquisition regulations to develop the logistic support plan. In addition, the materiel developer will perform such studies and tests as are necessary to insure that the following criteria are met:

(1) The weight and cubic volume of the system will not present an unacceptable logistics burden to either the using units or the combat service support system.

(2) The system components should be reusable to the maximum extent possible. This reusability must not degrade the system's employment, structural capabilities, nor require an inordinate amount of maintenance effort.

(3) The Logistical Support Plan will be available for evaluation at OT I.

(4) Develop RAM requirements to include operational mode, summary and mission profile, reliability and maintainability parameters.

d. Training Support Concept. The DARCOM materiel developer, in coordination with the TRADOC proponent, will develop a training support package to support the Tactical Bridging Access/Egress System.

(1) The materiel developer, in coordination with the TRADOC proponent, will develop a detailed training subsystem capable of providing a complete transfer of knowledge from the developer to the system user and maintainer. This training subsystem will be based upon a precisely defined set of performance requirements obtained through analysis or collection of logistic support analysis (LSA) data generated IAW DARCOM Pam 750-16 or MIL-M-63035, as appropriate. Based on the results of this analysis DARCOM/TRADOC will jointly agree upon a detailed task list covering all operator and maintenance difficult to train tasks for the system. The identification of and agreement of these tasks will be a formal, identifiable milestone in the validation phase of development. Tasks so identified will be incorporated into a signed agreement and into the system outline acquisition plan.

(2) TRADOC will describe the user population to the materiel developer and assist the materiel developer in identifying any unusual training requirements inherent in the intended user population.

(3) The DARCOM materiel developer will develop a synoptic outline of each TM to be produced, and preliminary draft documentation and storyboard training materials for high risk tasks IAW approved Skill Performance Aid (SPAS) specifications. Deliverable products for DT/OT I will be determined between DARCOM and TRADOC on a case-by-case basis. The draft documentation and training produced as a result of this determination will be used to train operator/crew and maintenance personnel representative of the user population for OT I. The Training Support Plant will be available for evaluation at OT I.

(4) The need for training requirements and materials, such as classroom trainers or collective trainers, which are not identified as a result of the SPA work effort, will be investigated. The necessary TRADOC/DARCOM responsibilities and resources to develop these training materials will be established and requirements will be included in the ROC or separate requirement documents, as appropriate.

(5) TRADOC will develop an Outline Individual and Collective Training Plan (OICTP), outlining the initial system training concept and strategy and as much of the individual and collective unit and institutional training requirements as known.

(6) The capability of the player personnel, trained with the draft documentation and storyboard training materials, to perform the high risk tasks to the required standards in the field phase of OT I will be made a critical test issue.

e. Personnel Support Plan. The materiel developer will minimize the number of tasks required by the operator and develop personnel

requirements estimates prior to DT/OT I to determine operational, support, and training projections. Particular attention will be given to simplicity, human factors engineering, and reliability of automatic features to minimize support costs, operator spaces, and mission response time.

ANNEX A
Mission Profile

Tactical Bridge Access/Egress System

THREAT:

WEAPONS POSING THREAT TO SYSTEM

	<u>CFA</u>	<u>MBA</u>	<u>DIV REAR AREA</u>	<u>CORPS REAR AREA</u>
Small Arms	X	X		
Artillery	X	X	X	X
Tanks	X	X		
ATGM	X	X		
TAC Air	X	X	X	X
Mines	X	X	X	X

BATTLE CONDITIONS: The Tactical Bridge Access/Egress System will be employed in the combat zone under conditions of low, mid, or high intensity conflicts.

GEORGRAPHIC AREA OF OPERATIONS: The primary area of operation for the foreseeable future is comparable to Western Europe. However, this system will be operated in climatic categories 1 through 6 under realistic battlefield conditions and adverse weather conditions.

MISSION: To provide trafficability for wheeled and tracked vehicles over soils and slopes normally impassable and to assist those vehicles in access/egress from river crossing sites. The system will consist of soil and bank reinforcement capable of being installed using personnel and equipment organic to engineer units.

a. Type Operations Undertaken:

<u>Type Operation</u>	<u>Rate of Employment</u>	<u>Manpower</u>	<u>Vehicle Passes</u>	<u>Vehicle Capacity</u>
Swim/Ford Vehicle Access/Egress	8 sites in 1/4 hr	4 squads	25	CL 60
Move Brg/Raft to Site	200 m/hr	10 men	50	CL 25
Sustained Traffic	400 m/hr	1 platoon	3000	CL 60 (10%)

b. Mission Requirements per Division:

	<u>Average Length of Lane/Mission</u>	<u>Mission Per Crossing Opn</u>
Swim/Ford	15 m	8
Move Brg/Raft to Site	120 m	4
Sustained Traffic	150 m	8

c. Site conditions to be overcome are those found adjacent to and in waterways found in Western Europe during all seasonal variations.

d. Estimated Percent of Time Employed in Each Area:

	<u>CFA</u>	<u>MBA</u>	<u>DIV REAR AREA</u>	<u>CORPS REAR AREA</u>
100%	20%	70%	10%	

MOBILITY: System can be transported on vehicle types presently organic to Combat Engineer Companies and Float Bridge Companies with no unacceptable degradation of the present mobility of those units.

OPERATIONAL ENVIRONMENT: 80% of employments will be at night in blackout conditions.

COUNTERMEASURES: Direct observation, sensors.

APPENDIX B

MEMORANDUM FOR RECORD--TRAFFIC TESTS ON
M19 AND M8A1 LANDING MATS FOR TACTICAL
BRIDGE ACCESS/EGRESS APPLICATIONS



DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESSS

11 April 1978

MEMORANDUM FOR RECORD

SUBJECT: Traffic Tests on M19 and M8A1 Landing Mats for Tactical Bridge Access/Egress Applications

1. During December 1977, accelerated traffic tests were conducted at the WES on M19 and M8A1 landing mats for the purpose of determining how these current inventory items could best be utilized for bridge access/egress applications. The M19 and M8A1 mats are depot stocked items which weigh 4.3 and 7.5 lb per sq ft, respectively. The M19 mat is a sandwich-type structure containing an aluminum honeycomb core bonded top and bottom to aluminum skins (Incl 1). The individual panels, 1.5 in. thick, 50-1/4 in. long, and 49-1/2 in. wide, weigh approximately 71 lb. The M8A1 rolled steel mat is fabricated from 0.125-in.-thick sheet material (Incl 2). Nominal dimensions of the M8A1 mat are 1 ft 7-1/2 in. wide by 11 ft 11-1/4 in. long, with an overall panel thickness of 1.125 in. The weight of this mat is 144 lb per panel.

2. The test section was located under a hangar-type structure to provide protection from the elements. The test section was excavated to a depth of 24 in. below grade and backfilled with a heavy clay. The test section covered an area 54 ft long and 12 ft wide, and consisted of items 1 and 2 as shown on Incl 3. An approach area was provided at each end of the test section to provide a maneuver area for the test vehicle during the application of traffic. The in-place CBR of the test section prior to traffic had an average of 0.5 for the top 12 in. Soil data are summarized on Incl 4. The test section prior to placement of mat is shown on Incl 5. The M19 and M8A1 mats were laid on the test section (Incls 6 and 7) and connected with an H-connector at their juncture (Incl 7). The M19 panels were placed in a normal brickwork pattern with the male-female joints parallel to the direction of vehicular traffic and continuous along the test item length (Incl 3). The M8A1 panels were placed in a pattern such that adjacent sides were joined by connectors consisting of bayonets and slots (Incl 3).

3. Traffic tests were conducted with a 5-ton military cargo truck and a M48A1 combat tank. The M54 cargo truck (Incl 8) was loaded with a 20,000-lb payload (gross weight, 40,000 lb) and the 11x20, 12-ply tires were inflated to 70 psi. These conditions represented the highway

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11 April 1978

SUBJECT: Traffic Tests on M19 and M8A1 Landing Mats for Tactical Bridge Access/Egress Applications

loading for the truck. The M48A1 tank (Incl 9) was loaded with 8000 lb (approximate gross weight, 106,000 lb). Traffic was applied in a channelized pattern similar to that which would be encountered in actual road conditions. Trafficking of the test section was scheduled for 2700 passes of the M54 truck followed with 300 passes of the M48A1 tank.

4. A view of the overall test section prior to traffic is shown on Incl 10 and a view of items 1 and 2 are shown on Incls 11 and 12, respectively. As the M54 truck moved across the test items, bow waves were very evident on item 2 (M8A1 mat); however, very little movement was noticed on item 1 (M19 mat). After 32 passes, the bow wave action on item 2 had caused some subgrade material to be forced from beneath the mat up through the joints and to the sides of the test section as the panels were being pushed into the subgrade by the truck. The maximum subgrade elevations along the edges of items 1 and 2 were approximately 1/2 and 6 in., respectively, higher than the adjacent mat surfaces. As traffic was continued, the M8A1 mat progressively sank and subgrade material continued to be pumped up through the joints and out along edges of the section. Inclosure 13 shows the condition that existed on item 2 after 70 truck passes. The maximum distance from the top of the subgrade adjacent to the mat edges and the mat surface on item 2 was 20 in. (Incl 14). The subgrade along the edges of item 1 after 70 passes was approximately 3/4 in. higher than the adjacent mat surface. A view of item 1 after 70 passes of the truck is shown on Incl 15.

5. After 150 passes, the truck rear wheels began to slip at the transition, where item 2 had been forced approximately 12 in. lower than item 1. As the vehicle was backing from item 2 onto item 1, the truck slid off the M8A1 mat into the subgrade (Incl 16). Although the M8A1 mat was not damaged, item 2 was considered failed due to the uneven surface of the mat which would hinder the maneuverability of a vehicle. Inclosure 17 shows the 36-in.-deep depression which formed as the M54 truck slid off item 2. The maximum change in both cross-section (Incl 18) and profile (Incls 19 and 20) measurements from the beginning to 150 passes of the truck on item 2 was 17.6 and 16.6 in., respectively. Profile and cross-section measurements on item 1 are shown on Incls 19-21. The M19 mat (item 1) remained undamaged after 150 passes of truck traffic (Incl 22).

6. At the completion of 150 passes, traffic was discontinued on the item 2 matting (M8A1). Traffic was then continued with the truck on the M19 mat. After the completion of 2700 truck passes, no visible damage had occurred to the M19 mat (Incl 23). The subgrade elevation along the edges of item 1 measured up to 4 in. higher than the adjacent mat surface (Incl 24). The maximum change in both cross-section (Incl 25) and

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SUBJECT: Traffic Tests on M19 and M8A1 Landing Mats for Tactical Bridge Access/Egress Applications

profile (Incl 26) measurements from the beginning to 2700 truck passes was 1.7 in.

7. To evaluate the effects of tank traffic on the mat, the M48A1 tank was used to traffic the test section at the completion of the truck tests. After 2 passes of the M48A1 tank, the outer edges of M19 mat were pushed down into the subgrade approximately 6 in. As the tank was removed from the test area, the outside edges of the mat sprang upward 3 in. and were suspended by the continuous male-female joint running parallel to the direction of traffic. The maximum distance from the top of the extruded subgrade to the top mat surface was 7 in. and occurred adjacent to the west edge of the test section (Incl 27). The two outside runs of mat were compressed further into the subgrade on each successive pass of the tank. This continuous stress on the top lip of the male connector eventually caused the connector to break for a total of 20 continuous ft or 6 panels after 56 passes of the tank, and the bottom of the tank began dragging on the mat surface. A view of item 1 at the conclusion of traffic is shown on Incl 28. The subgrade elevation adjacent to the mat edges measured approximately 20 in. higher than the mat surface (Incl 29). The maximum change in cross-section (Incl 25) measurements from 2700 truck passes to 2756 total passes was 7.8 in. and occurred along the west edge of the test section. The maximum change in the profile measurements due to tank traffic taken parallel to traffic and in the traffic line west of the center line (Incl 26) was approximately 4 in.

8. Results of this investigation indicated that:

a. The M8A1 mat will sustain 150 passes of a M54 truck loaded with a gross weight of 40,000 lb when placed on a clay subgrade with a CBR of 0.5. The M8A1 mat was not damaged; however, the uneven surface of the mat which existed after 150 passes was considered a hindrance to vehicle maneuverability.

b. The M19 mat will sustain 2700 passes of a M54 truck loaded with a gross weight of 40,000 lb and an additional 56 passes of a M48A1 tank loaded with a gross weight of 106,000 lb when placed on a clay subgrade with a CBR of 0.5.

9. It is recommended that further traffic tests on M8A1 and M19 mats be conducted on a 1 to 2 CBR subgrade. The future testing program should include trafficking tests on the M8A1 mat both with and without mat

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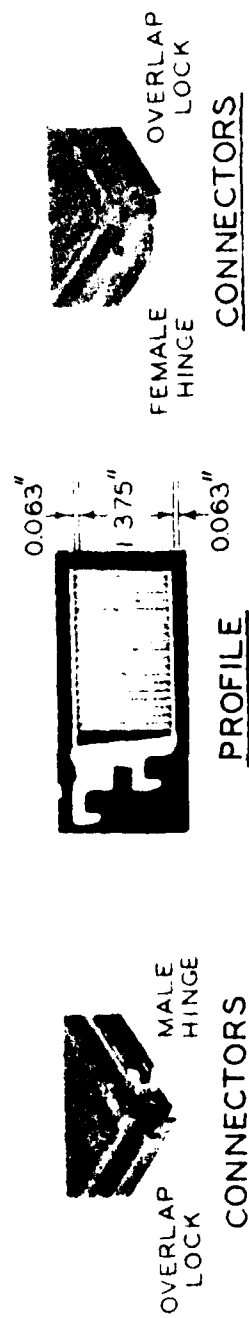
SUBJECT: Traffic Tests on M19 and M8A1 Landing Mats for Tactical Bridge
Access/Egress Applications

runners and on various lay patterns of M19 mat. The results of these traffic tests should be used for guidance in future investigations.

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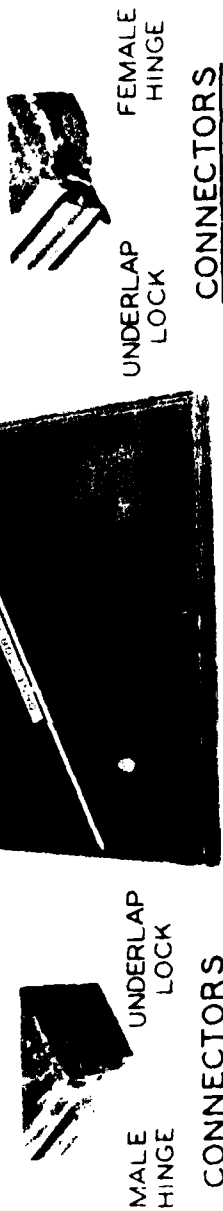
Carroll J. Smith
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Landing Mat Branch

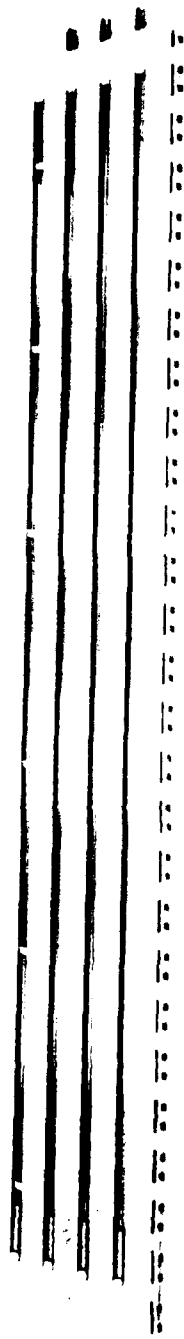
CF w/incl:
DRDME-M/Mr. K. K. Harris
DRDME-MD/Mr. W. R. Abell



PLAN OF PANEL
NOMINAL DIMENSIONS
 4'-2 1/4" x 4'-1 1/2"

Composite view of M19 aluminum landing mat



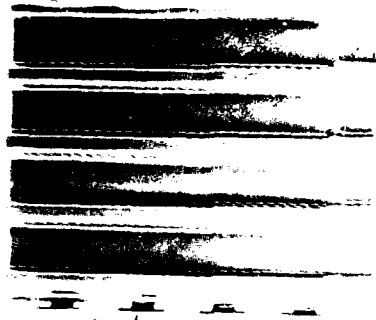


PLAN VIEW OF PANEL
NOMINAL DIMENSIONS
1'-7" x 11'-9"

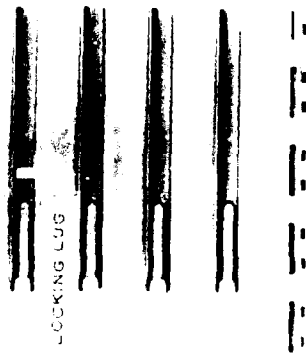


VIEW OF LEFT END

SIDE CONNECTOR
HOOKS



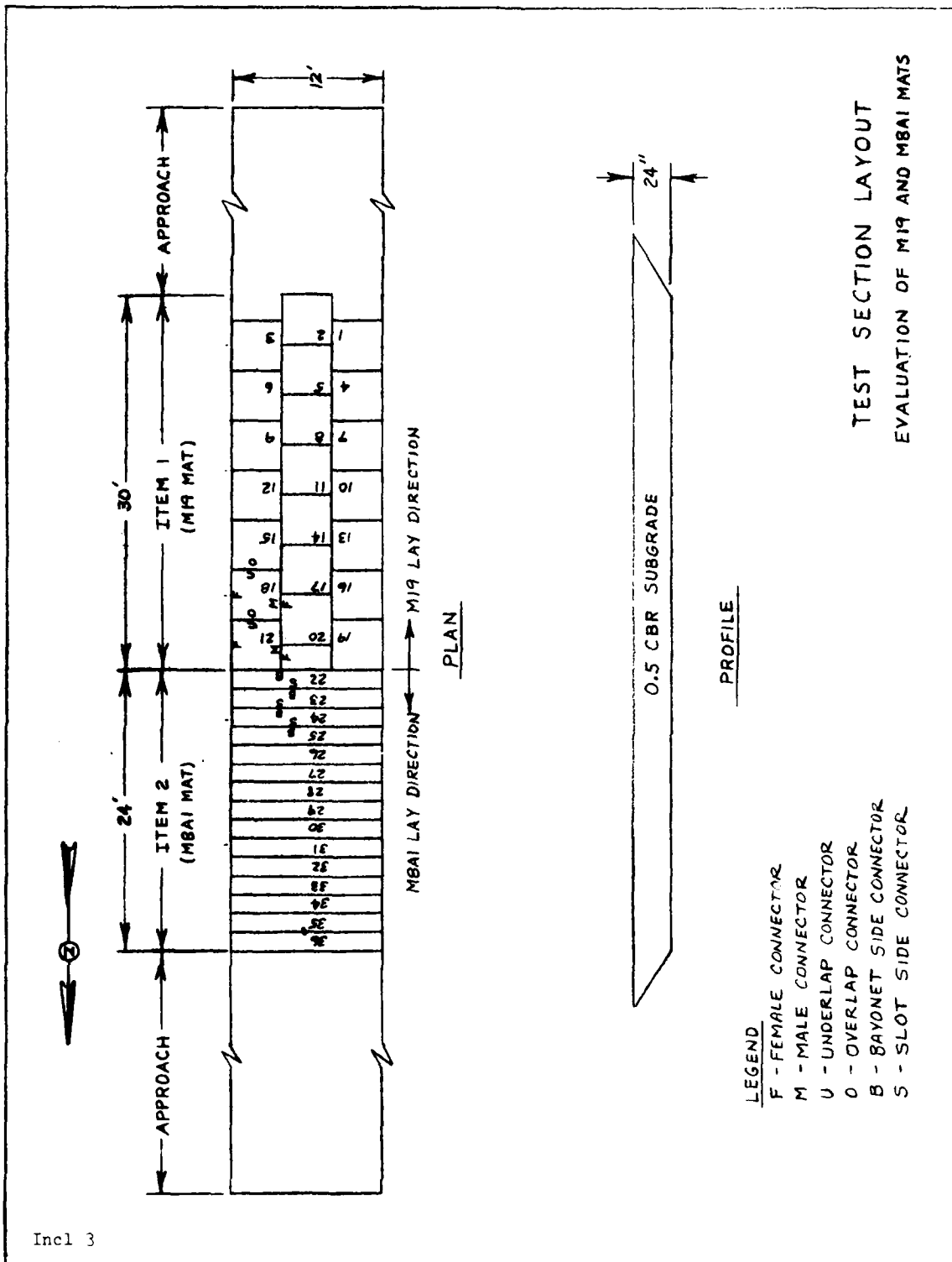
BOTTOM VIEW RIGHT END



DETAILS LEFT END



Composite view of M8A1 steel landing mat



SUMMARY OF WATER CONTENT, DRY DENSITY, AND CBR DATA

NUMBER OF PASSES	LOCATION	DEPTH IN.	WATER CONTENT %	DRY DENSITY PCF	CBR
0	CENTER OF PANEL 22	0	49.1	68.0	0.5
		6	48.9	68.5	0.5
		12	49.2	67.8	0.6
		AVG.	49.1	68.1	0.5
2756	CENTER OF PANEL 11	0	48.6	67.1	0.5
		6	48.4	67.3	0.5
		12	48.6	67.2	0.5
		AVG.	48.5	67.2	0.5

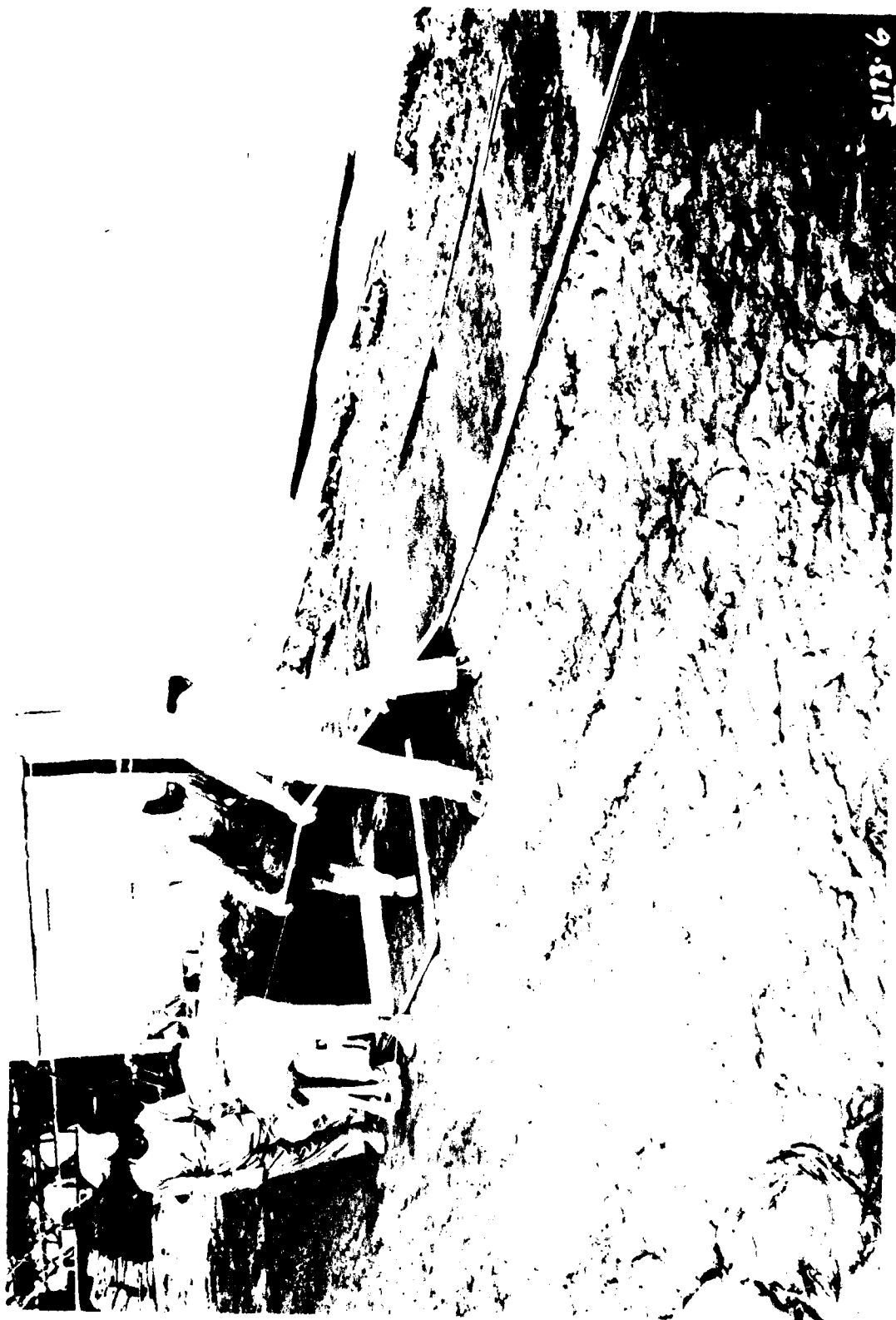
Incl 4



View of test section prior to placement of mat

Incl 5

53



Placement of MT9 mat



Placement of M8A1 mat

Incl 7



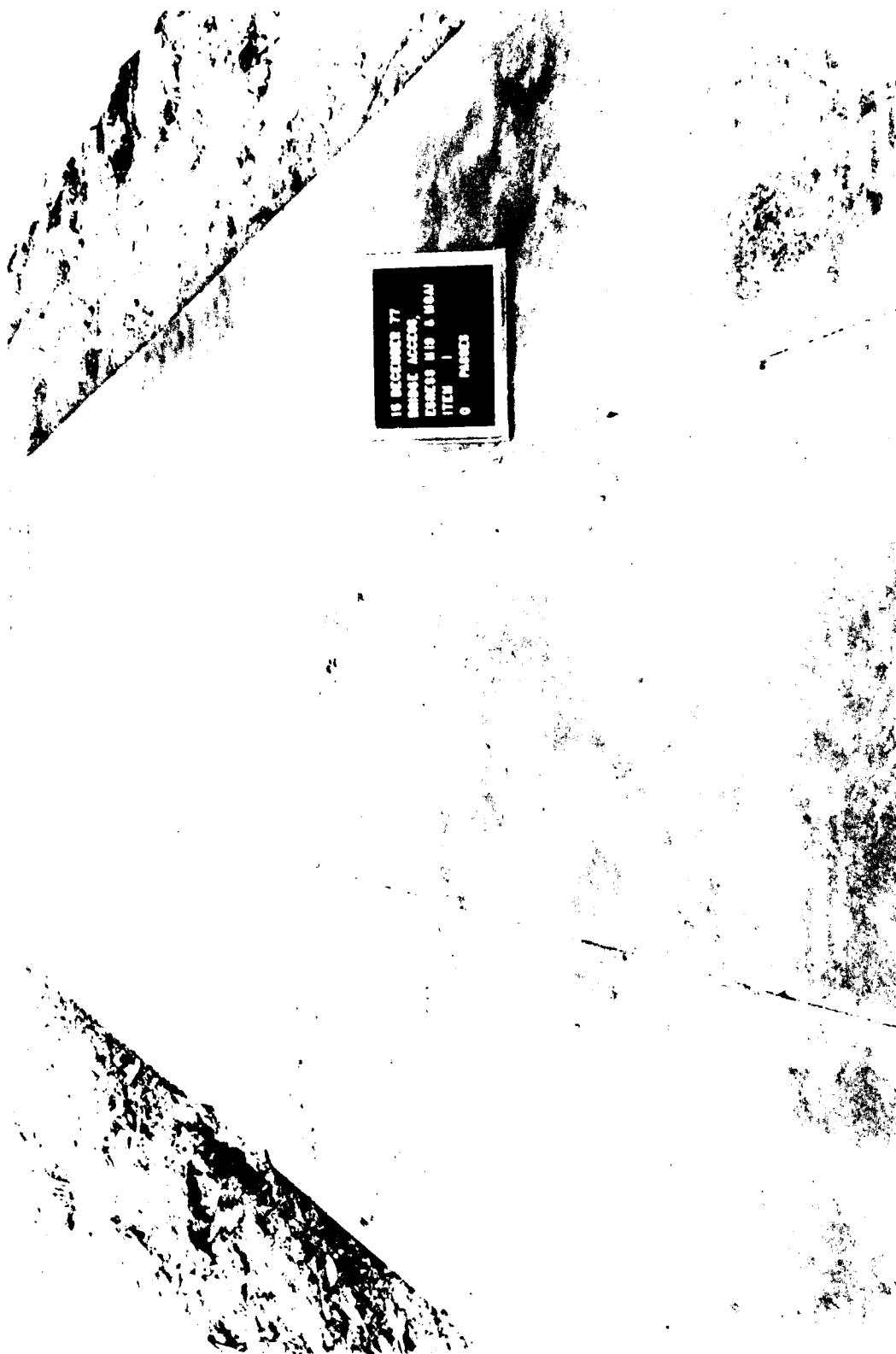
View of 5-ton, M54 cargo truck loaded to 20,000 lb (gross weight, 40,000 lb)



View of M48A1 combat tank loaded to 8000 lb (gross weight, 106,000 lb)

16 DECEMBER 77
BRIDGE ACROSS
RIVER M10 & 604M
ITEMS 1,2
0 PAGES

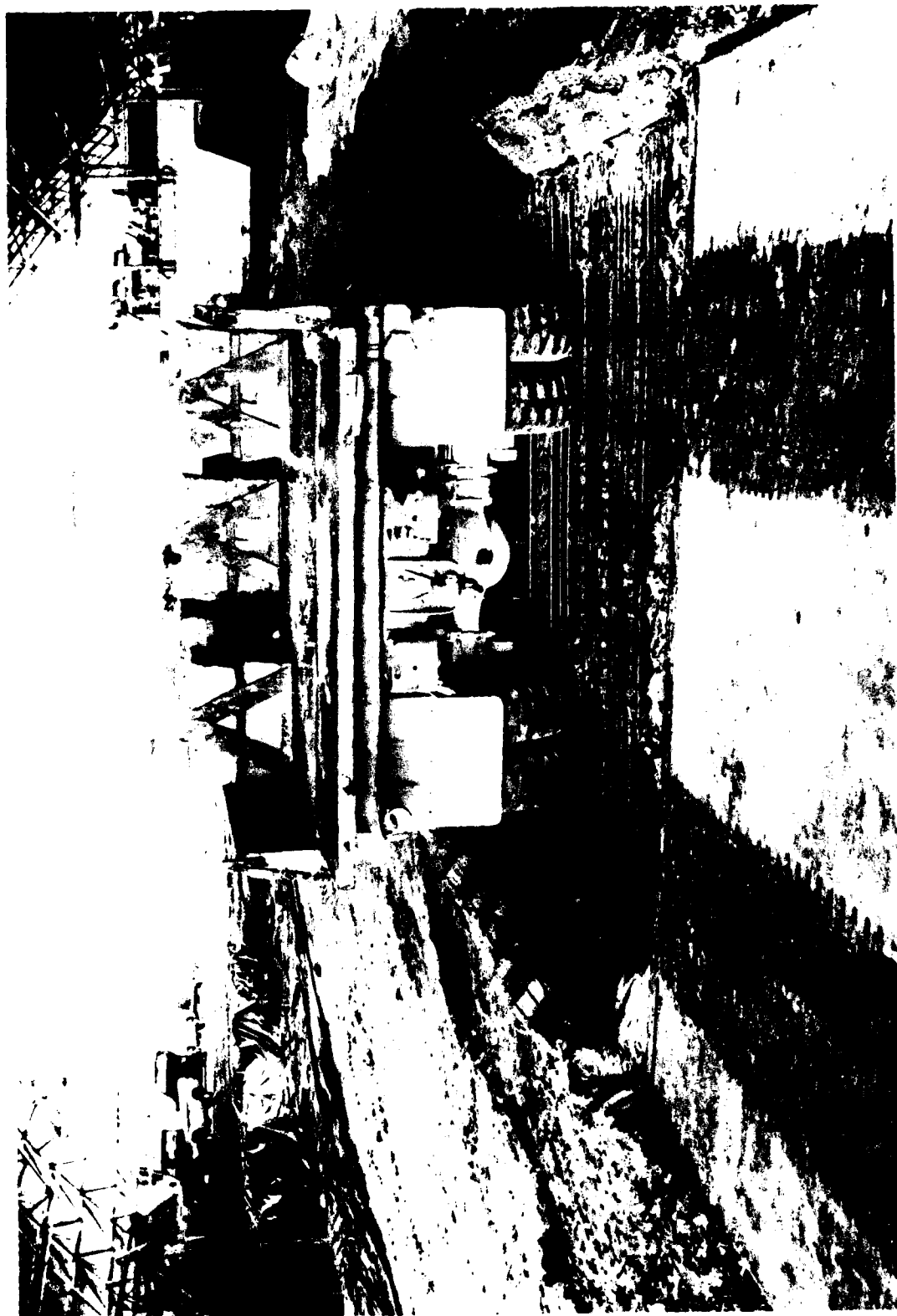
View of test section prior to traffic



Item 1 (1119 mat) prior to traffic



Item 2 (M8A1 mat) prior to traffic



View of the 5-ton truck positioned on M8A1 mat after 70 passes



Close-up of the rear truck wheels on #841 mat after 70 passes

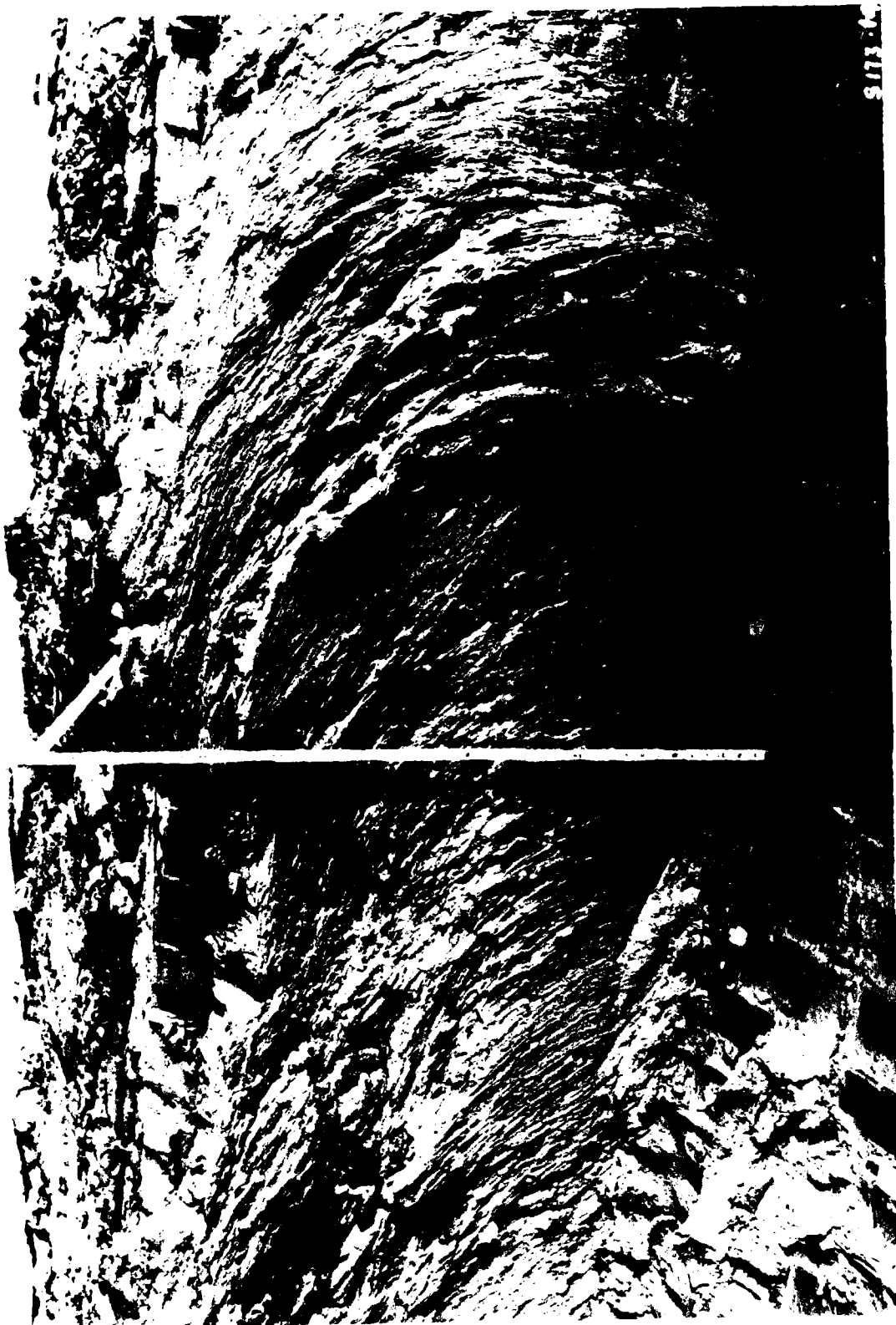


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Figure 1 (27 x 100) showing typical pattern

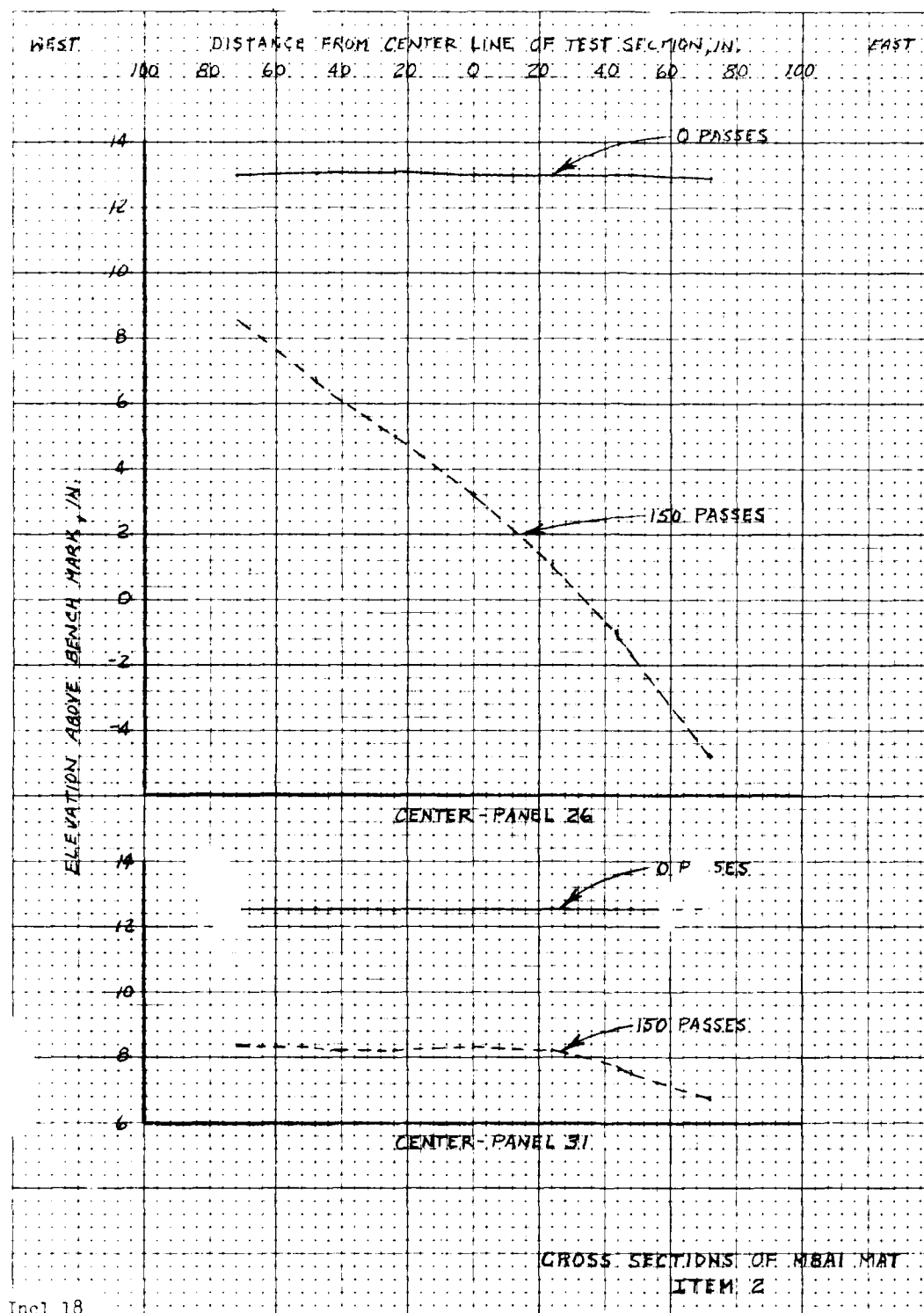


Item 2 after 150 passes. (Note the right side where the M54 truck slid off the M8A1 mat.)

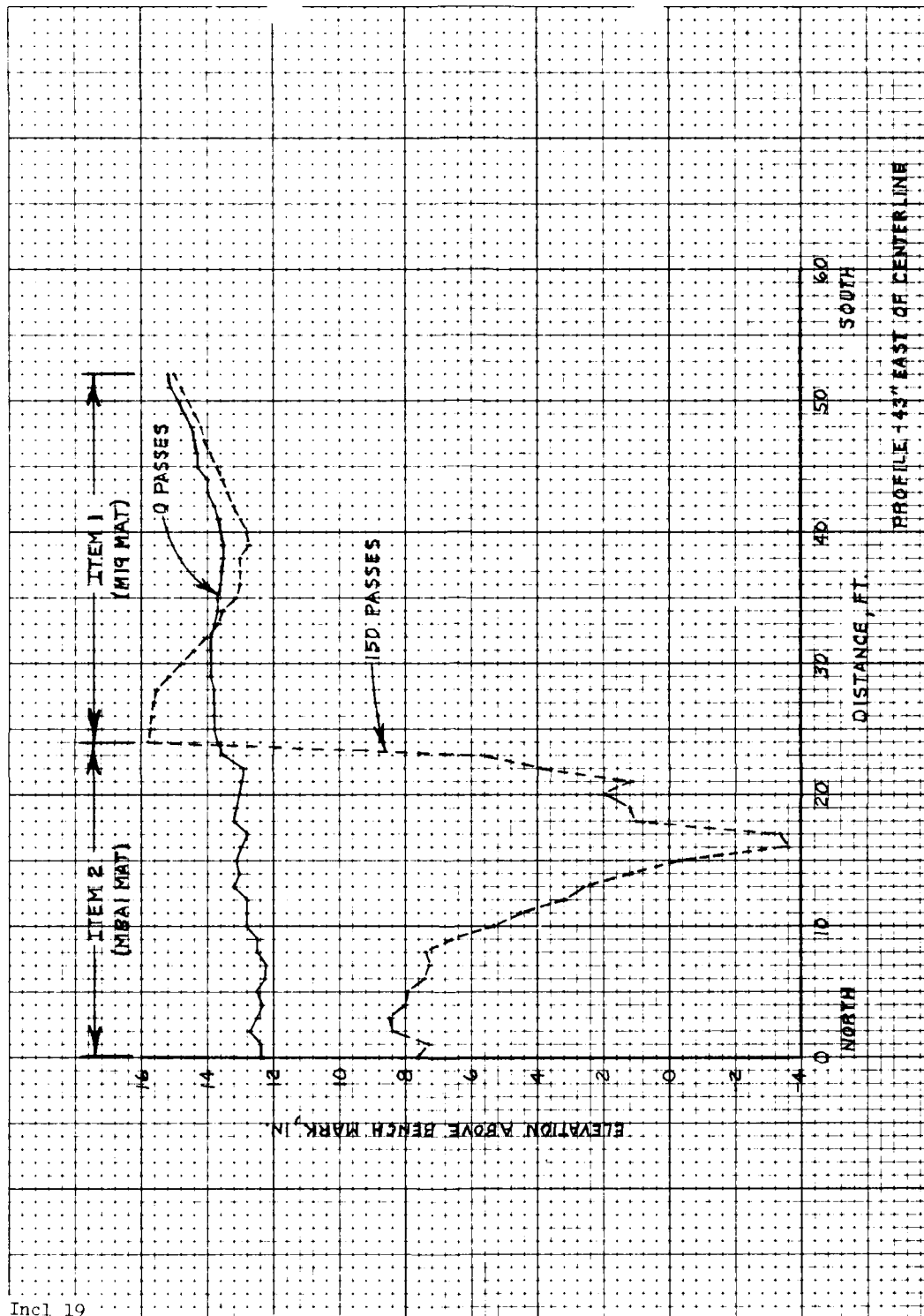


Close-up of the 36-in.-deep depression where the truck rolled off the M841 mat

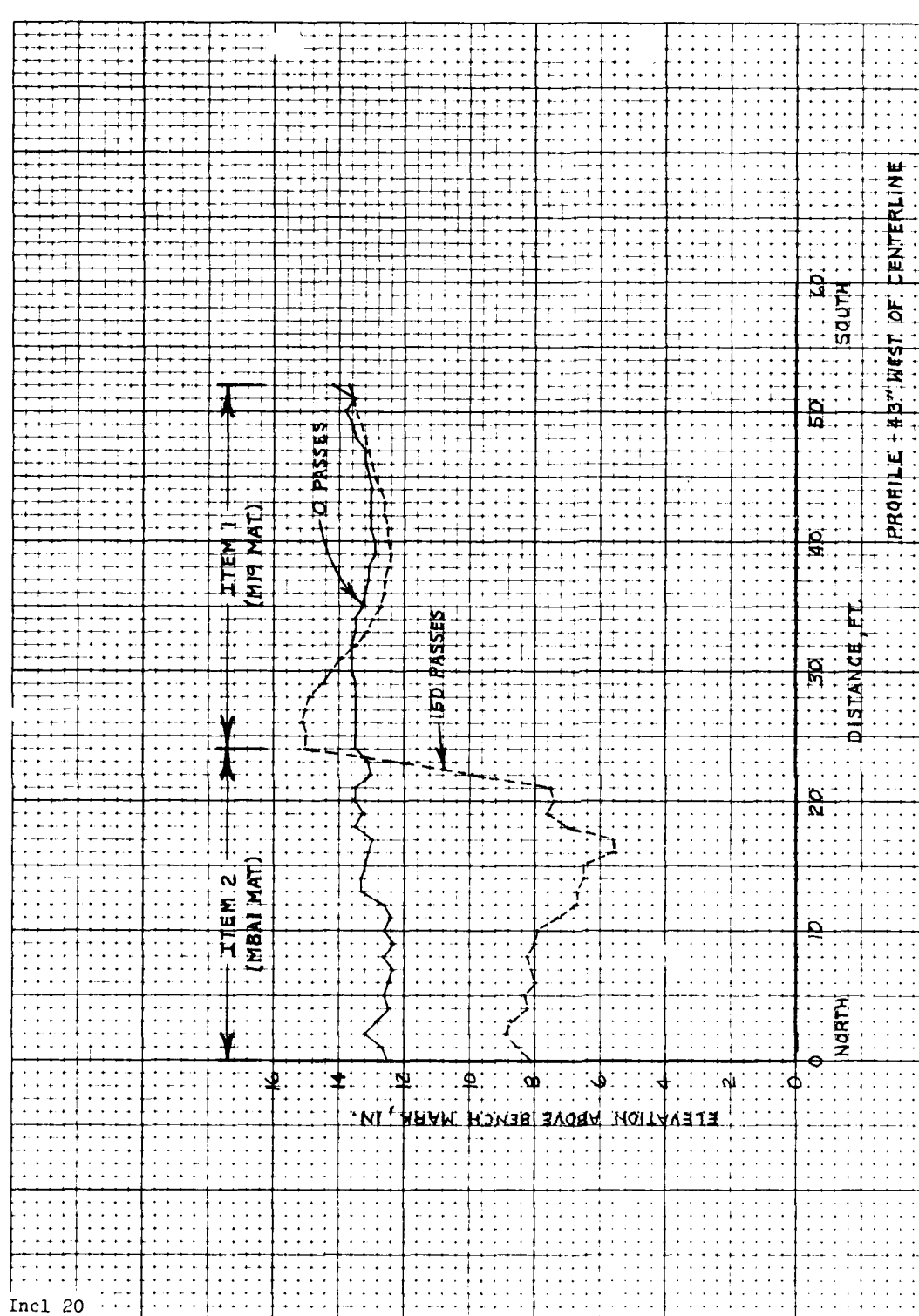
Encl. 17



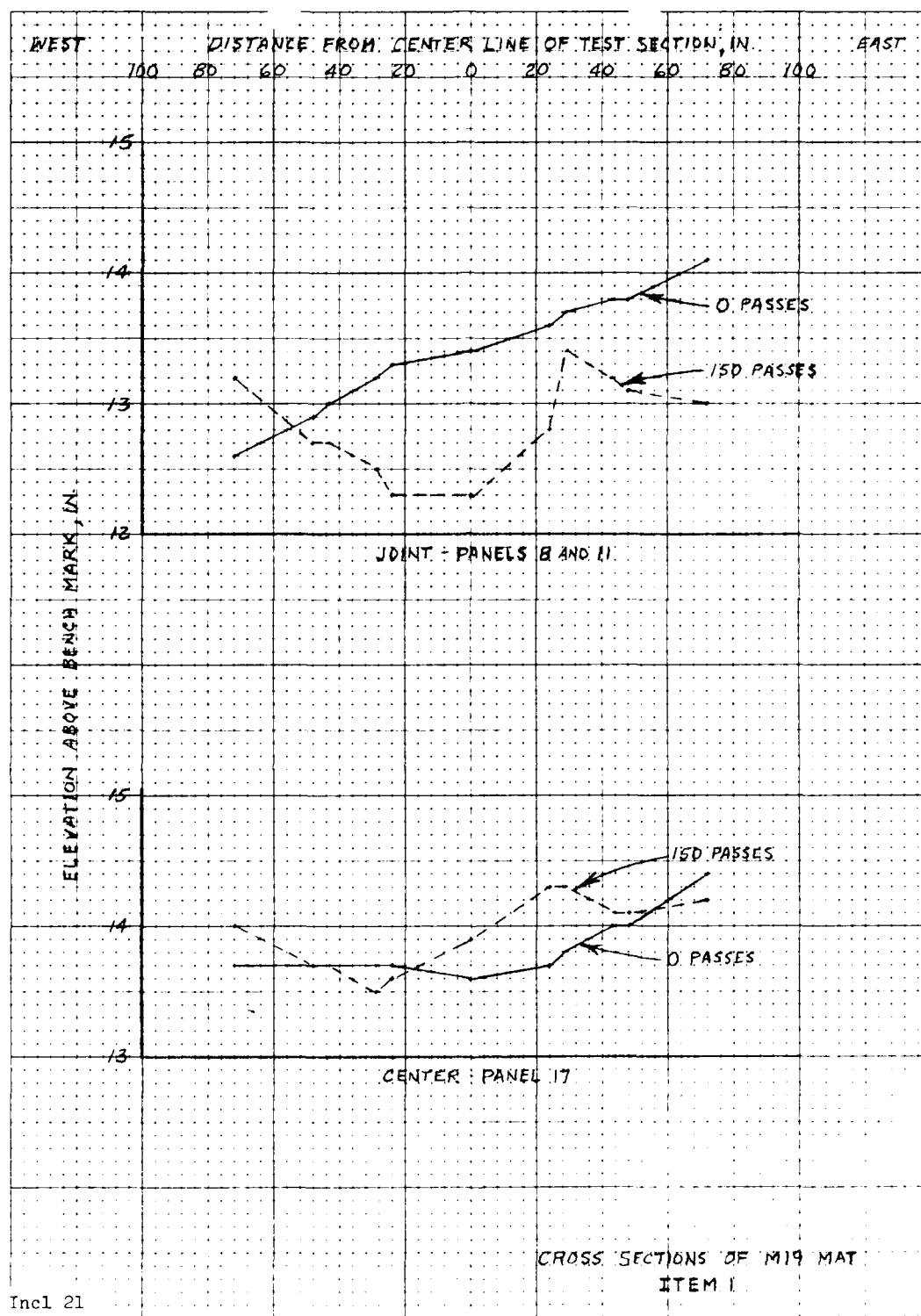
Incl 18



Incl 19



Incl 20



Incl 21



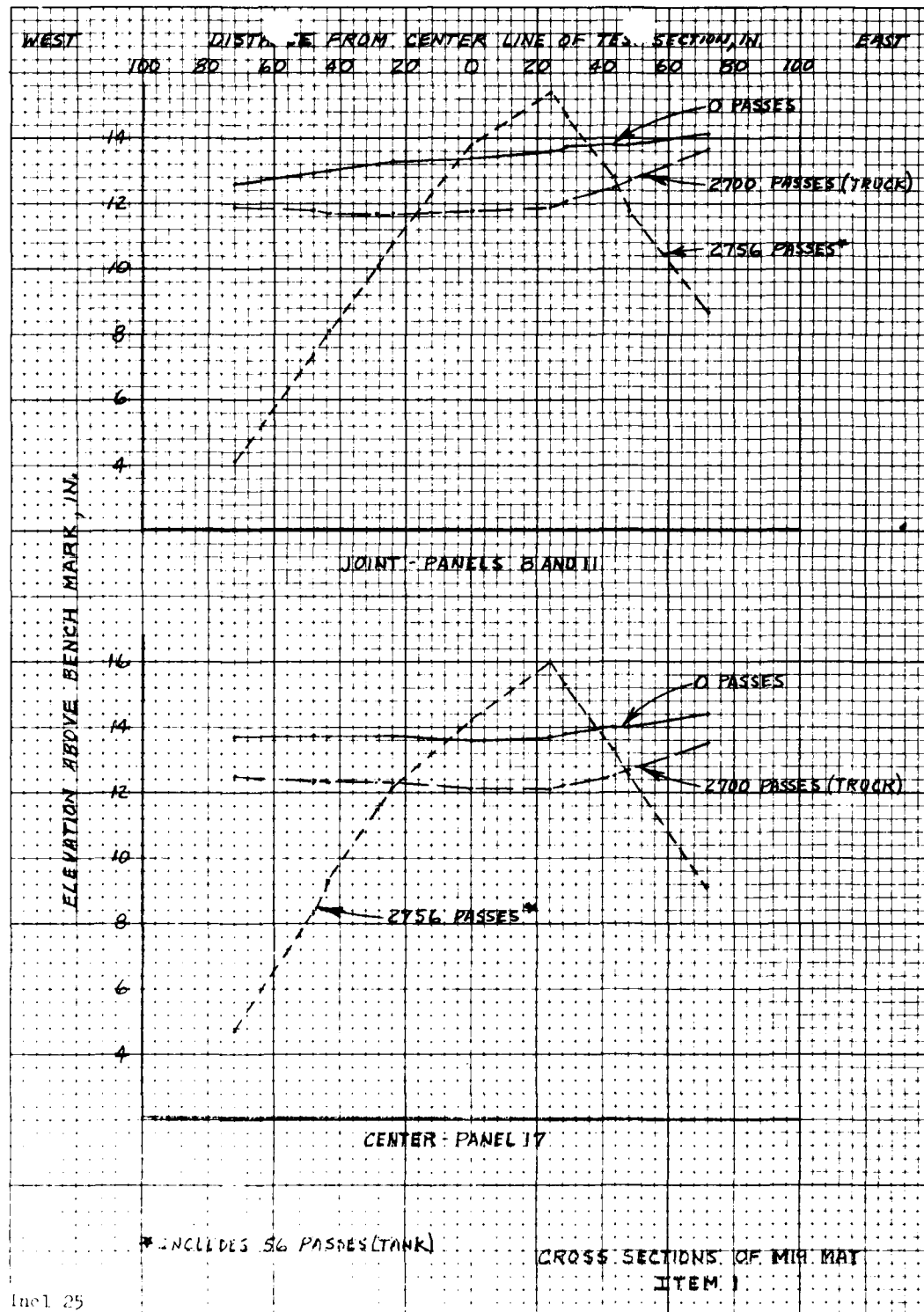
Item 1 after 150 truck passes



Item 1 after 2700 passes of a 5-ton truck



Close-up of mat edge and subgrade after 2700 truck passes



Incl 25

Incl 26

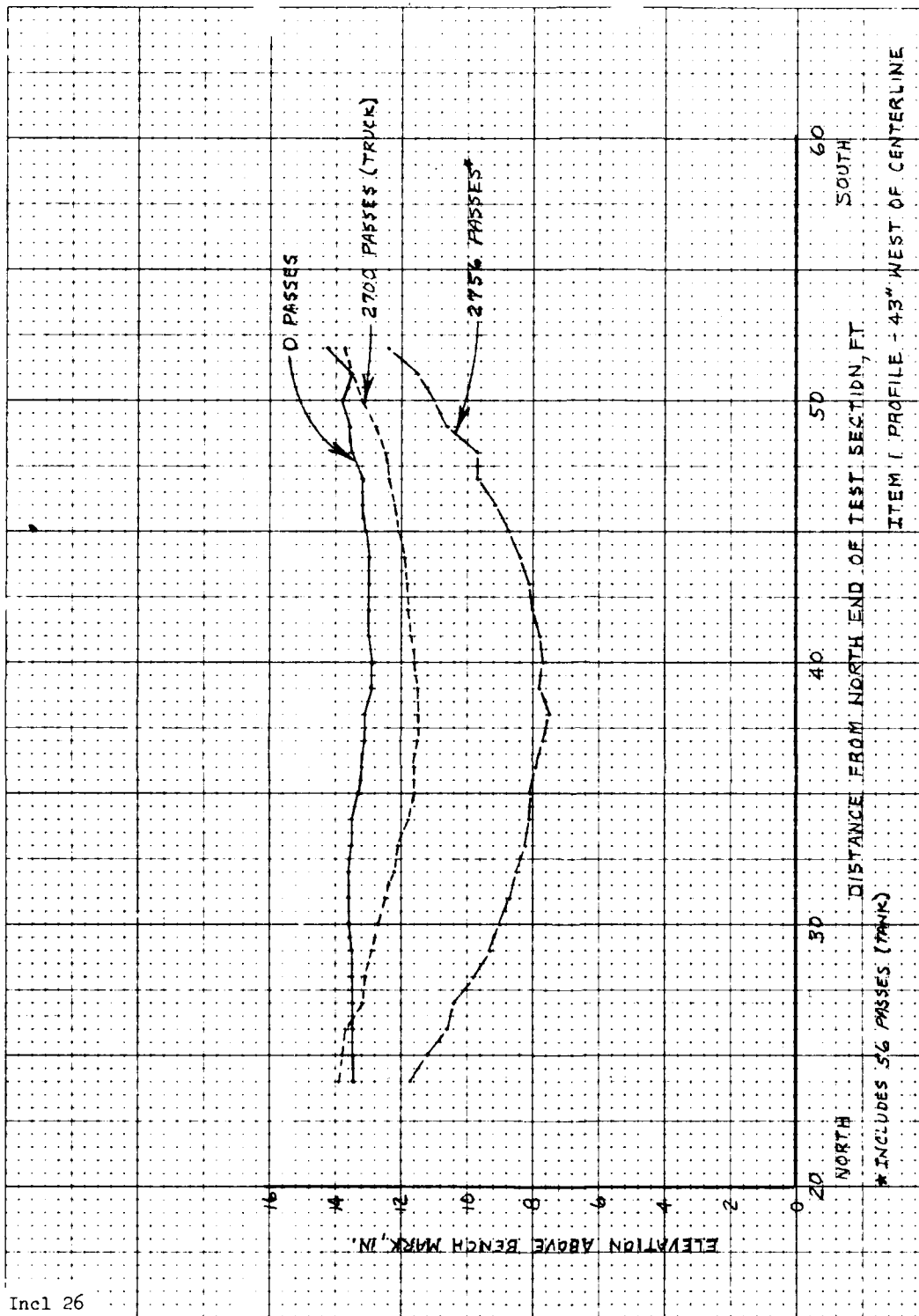




Photo 1 after 2 pairs of M-9 tank and 2nd M-9 tank



Item 1 after 56 passes of M48 tank and 2700 passes of M54 truck



Figure 1. Photograph of the interior of the cave, showing the entrance to the chamber.

APPENDIX C

MEMORANDUM FOR RECORD--EVALUATION OF M8A1
MAT FOR BRIDGE ACCESS/EGRESS SURFACING



DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO WES88

16 May 1978

MEMORANDUM FOR RECORD

SUBJECT: Evaluation of M8A1 Mat for Bridge Access/Egress Surfacing

1. During the period January-February 1978, traffic tests were conducted at the Waterways Experiment Station on M8A1 mats for the purpose of determining how this inventory item could best be utilized for bridge access/egress applications. The M8A1 steel landing mat panel (Incl 1) is approximately 12 ft long by 19 in. wide and 1 in. thick and weighs 144 lb or 7.5 lb/sq ft. The panels were fabricated from FS-1015 or -1020 (same as current AISI, C-1015, and C-1020) steel having a minimum yield strength of 33,000 psi conforming to Federal Specification QQ-A-00640. The 1/8-in.-thick material is formed into ribbed panels by a steel rolling mill. During placement, the panels are hooked together along the sides (12-ft length) by inserting the connector hooks into the connector slots while holding the panels at 35 to 40 degrees to each other. After engagement, the panel is slid approximately 1 in. to align the locking lugs with the corresponding slots and dropped into position. The locking lugs when engaged in the locking lug slots prevent lateral slippage of the panels.

2. The test section, which was 52 ft long and 15 ft wide with the subgrade processed to a depth of 24 in. (Incl 2), was located under a hangar-type structure to provide protection from the elements. The subgrade material was a heavy clay (buckshot), processed (Incl 3) to a controlled water content, and placed in the section in two lifts by dump truck (Incl 4). The bottom and sides of the subgrade were lined with polyethylene sheeting to prevent the material from drying out. The subgrade was spread with a D4 Caterpillar and compacted with a Roy Go Vibrator Romper (Incl 5). An approach area was provided at each end of the test section to provide a maneuver area for the test vehicles in the application of traffic. A summary of the soil data is presented on Incl 6.

3. The test section was divided into three items (Incl 2) to test three placement patterns. In all items the panels were placed as previously described. In addition, items 2 and 3 were placed on M8A1 runners spaced 10 ft apart from center to center (Incl 7). In item 3, the runners and panels were welded at four places on each run of mat with each weld approximately 2-1/2 in. long (Incl 8). No welds were used in item 2, but the panels were in contact with the runners. All items were generally smooth with a transverse slope from east to west. A general view of the section prior to traffic is shown on Incl 9.

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SUBJECT: Evaluation of M8A1 Mat for Bridge Access/Egress Surfacing

4. In-place subgrade densities, water content, and CBR's of the soil were measured before, during, and after traffic tests and are given on Incl 6. These measurements were made at the surface of the subgrade and at depths of 6 and 12 in., with a minimum of three values at each depth. Elevation measurements of the mat surface (transverse and longitudinal) were recorded before, during, and after traffic to determine permanent deformation of the test section and to reveal the development of roughness. These readings are shown on Incls 10-15. Visual observations of the mat, subgrade behavior, and other relevant factors were recorded throughout the period of traffic and were supplemented by photographs.

5. Mixed traffic was applied with two military vehicles. The 5-ton, M54 cargo truck (Incl 16) had a gross load of 40,000 lb distributed on 10, 11 x 20, 12-ply tires inflated to 70 psi. This vehicle was used in applying 2700 vehicle passes. The M48A1 combat tank (Incl 17) with a gross load of 106,000 lb was used to apply 300 passes for a grand total of 3000 mixed passes. The sequence of traffic was truck 0 to 1800 passes, tank 1801 to 2000 passes, truck 2001 to 2450 passes, tank 2451 to 2500 passes, truck 2501 to 2950 passes, and tank 2951 to 3000 passes.

6. Item 1 traffic test (M8A1 mat--no runners). Prior to traffic, the mat surface was generally smooth (Incl 18) but contained a transverse slope from east to west of approximately 4 in. (Incl 10). The CBR of the subgrade before traffic was 1.2 (Incl 6), and the loaded M54 truck caused the mats to rock (undulate) and seat into the soil on the initial passes. The panels were forced down by traffic and/or the subgrade was being forced to the edges of the mat. Some soil was being extruded up onto the mat surface through the connector and locking lug slots. After 200 passes, the mat surface was from 1 to 2 in. lower (Incls 10 and 13) than at the beginning of traffic. The subgrade on the east edge was over 3 in. higher than the adjacent mat surface (Incl 19). However, there were no breaks nor unusual wear noted in the mats.

7. The item remained in good condition and performed satisfactorily as traffic continued. At 1000 passes, the subgrade on the west edge was 6 in. higher than the adjacent mat surface (Incl 20) even though the mat had sprung (rebounded) up to 2 in. off of the underlying subgrade. After 1800 passes, the subgrade on the west edge was approximately 12 in. higher than the adjacent mat surface (Incl 21), and the mat was above the underlying subgrade 2 in. The panels were deformed somewhat, and measurements (Incl 22) indicated a maximum change from a 12-ft straightedge to be 3/4 in. in item 1. The cross sections and profile data (Incls 10 and 13) showed that the mat surface generally changed uniformly between 200 and 1800 passes.

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SUBJECT: Evaluation of M8A1 Mat for Bridge Access/Egress Surfacing

8. The M46A1 tank tracked the section for the next 200 passes (1801 to 2000 total). The overall track width of 143 in. almost matched the panel width of 144 in., and the slight maneuvering required in guiding the tank caused portions of the tracks to wander off of the mat edges part of the time. The tank forced the ends of the mats into the subgrade, but the mat ends would spring back after the tank moved off. After 1830 passes, the mat ends were 4 in. higher than the underlying subgrade; and after 2000 passes, they were 5 in. higher. A general view of the item after 2000 passes is shown on Incl 23. Cross sections and profile curves (Incls 10 and 13) show very little change in the mat surface caused by the 200 passes of the tank. Soils data (Incl 6) taken in the east wheel path indicate an increased strength of 0.2 CBR. After 2450 passes, the truck traffic caused the mat's edge (east) to be off of the subgrade only 2-1/2 in.; but after the next 50 passes of the tank, the mats were off of the subgrade over 4 in. After 3000 passes, the panels were still in good condition, but some permanent set was noted (Incl 22). Cross section and profile curves (Incls 10 and 13) indicate the mat surface has changed an average of approximately 4 in. during the tests. The item after 3000 passes is shown on Incl 24.

9. When the panels were removed, three panels had the end (east) connector hook broken off at the base, and five other panels had a crack at the same connector hook. Three other cracks were noted at the connector hook on the panels. The cracks were less than 1/2 in. long. The panels were reconnected by four men in the same position as previously connected, and it required 22 minutes to connect five panels.

10. Item 2 traffic test (M8A1 mat--runners, no welds). Prior to traffic, the mats had a transverse slope (Incl 11) from east to west, but the surface was generally smooth (Incl 14). A general view of the item is shown on Incl 25 at zero passes. The load wheels of the truck were 97 in. from outside to outside, and they ran just inside the runners which were approximately 100 in. apart (inside edge to inside edge), and this caused the mats to become permanently set with traffic which was noted at 20 to 30 passes and had increased to 1-1/2 in. as shown on Incl 22 after 1800 passes. No breaks or damage were noted at this time. The mats were seated an average of approximately 1 in. during the first 200 passes and increased only slightly up to 1800 passes (Incls 11 and 14). Inclosure 22 shows the panels were uniformly dished 1-1/2 in. A closeup of the item is shown on Incl 26 after 1800 passes.

11. The tank traffic embedded the runners further into the subgrade from 1800 to 2000 passes, but the mats sprung back off of the runners 1 in. after 1850 passes and were up 2 in. after 2000 passes (Incl 27). The 200 passes of the tank caused very little change in the mat surface as revealed

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10 May 1978

SUBJECT: Evaluation of M8A1 Mat for Bridge Approaches/Exposed Surfacing

by the level readings (Incls 11 and 14). The panels were dished less after the tank traffic than at 1800 truck passes as shown by panel 14 on Incl 22. The average CBR after 2000 passes taken in the east wheel path under panel 15 was 1.4 (Incl 6).

12. The mat surface elevation changed an average of approximately 1/2 in. (Incls 11 and 14) between 2000 and 3000 passes, and the dishing measurement had reduced slightly (Incl 22). The mats were still 2 in. off of the runners. Inclosure 28 shows the item at the end of traffic.

13. When the panels were removed, two 1/4-in. breaks were discovered at the base of connector hooks. The mats were in good condition and in a trial relay were relaid without any unusual difficulties.

14. Item 3 traffic test (M8A1 mat--welded runners). The mat surface in item 3 was generally smooth at the beginning of traffic with a transverse slope from east to west (Incls 12 and 15). An overall view of the item prior to traffic is shown on Incl 29. Approximately 70 percent of total mat embedment during the test was produced during the first 200 passes of truck traffic (Incls 12 and 15).

15. There was less movement of panels caused by traffic in item 3 than in the other items. The truck load wheels ran inside the runners and caused the panels to dish during the first 1800 passes of traffic a maximum of 1-3/4 in. as shown on Incl 22. The tank traffic was then applied along the panel edges, embedding the runners, eliminating some of the dishing (1-3/4 in. after 1800 passes versus 1 in. after 2000 passes), and caused the runners to rebound above the subgrade approximately 2 in.

16. After 3000 passes, the runners were still above the underlying subgrade, and the dishing was less than at either 1800 or 2000 passes (Incl 22). The item is shown at the end of traffic in Incl 30.

17. After the panels were removed, a visual inspection of panels revealed that two panels had one weld each that had broken. The panel welds were cut with a torch for removal; and except for torch damage, the panels were in good condition for reuse. The soil data (Incl 6) show that the subgrade strength had only increased from 1.2 to 1.4 CBR during the test period.

18. Results of this investigation indicated that:

a. All of the test items sustained 3000 passes of mixed truck and tank traffic and were serviceable for continued traffic.

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16 May 1971

SUBJECT: Evaluation of MSAI Mat for Bridge Access/Egress Surfacing

b. Item 3 (welded runners) embedded into the subgrade (surface elevation change) less than item 2 (Incls 12 and 15 versus Incl 11 and 14), and item 2 embedded less than item 1 (Incls 11 and 14 versus Incls 10 and 13).

c. From visual observations, there was more mat movement in item 1 under traffic than in the other two items, and item 3 had the least mat movement.

d. It was considered feasible to reuse the panels from item 2 and 3 but somewhat doubtful that the panels in item 1 were suitable for reuse because of the time and effort that would be required to reconnect the panels.

e. Item 3 panels had some holes which were made by the cutting torch when the welds were cut for panel removal but otherwise were in good condition.

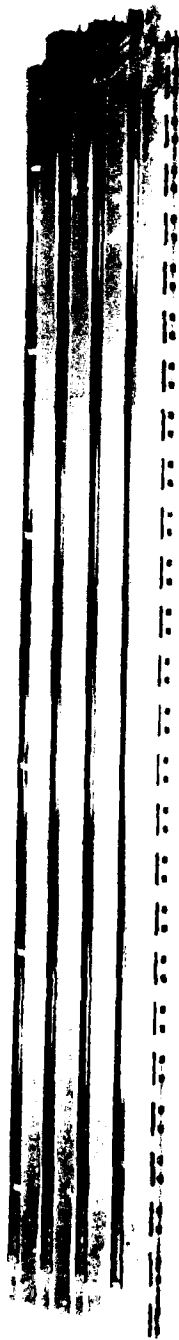
19 Based on results of these tests, it is concluded that MSAI mat without runners will support the required traffic. Additional tests of MSAI mat without runners will be conducted with membrane underlay to determine membrane performance in preventing extrusion of soft subgrade material through mat joints.

30 Incl
as

CF w/incl:
DEUCE-M
DEUCE-MD

G. L. Carr

G. L. Carr
Civil Engineering Technician
Landing Mat Branch



PLAN VIEW OF PANEL
NOMINAL DIMENSIONS
1'-7 1/2" x 11'-9 3/4"

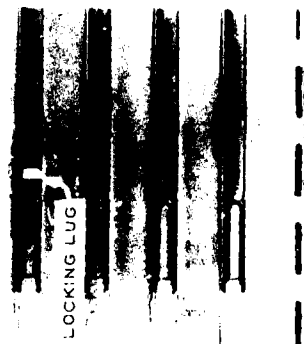


VIEW OF LEFT END

SIDE CONNECTOR
HOOKS



VIEW OF RIGHT END

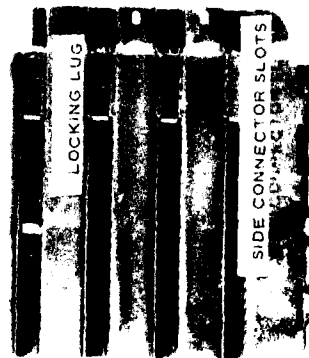


LOCKING LUG

DETAILS LEFT END



BOTTOM VIEW RIGHT END



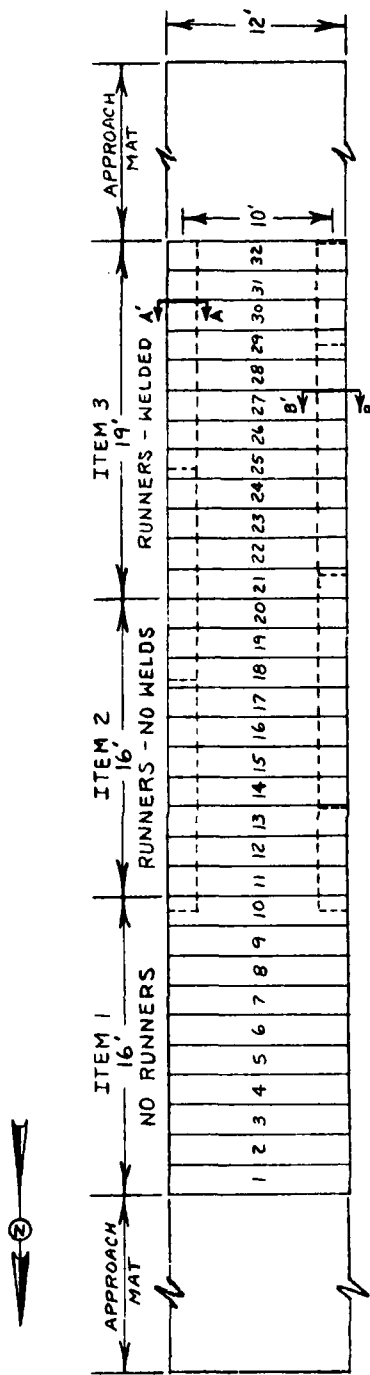
LOCKING LUG

1 SIDE CONNECTOR SLOTS

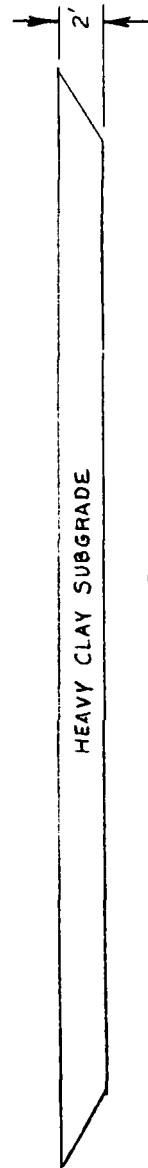
DETAILS RIGHT END

M8A1, STEEL LANDING MAT

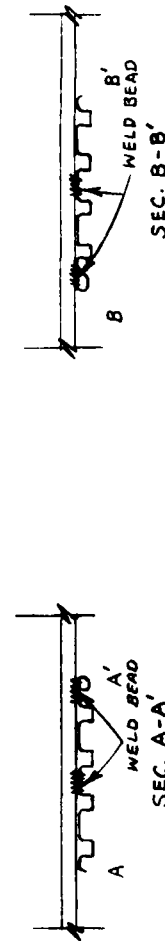
Incl 2



PLAN



PROFILE



TEST SECTION LAYOUT
EVALUATION OF M8AI MAT

Test section layout



Heavy clay (brickshut) being processed



Heavy clay being unloaded in test section

Incl 4



Compacting the subgrade

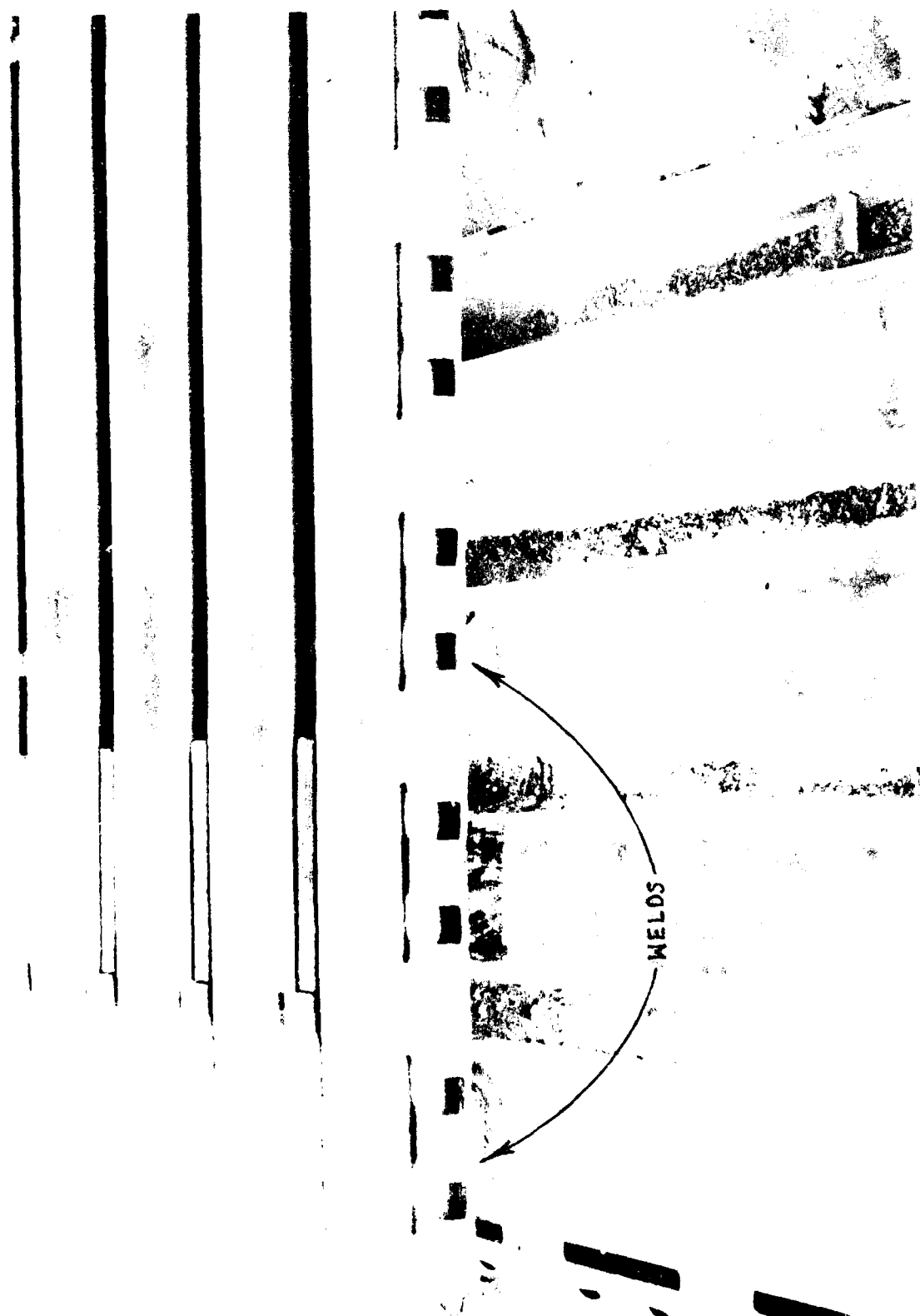
Incl 5

SUMMARY OF CBR, WATER CONTENT, AND DENSITY DATA

Number of Passes	Location	Depth in.	Water Content %	Dry Density pcf	CBR	Rated CBR
0	Panel 17	0	34.0	82.1	1.3	
	Ø	6	33.7	82.7	1.1	
		12	33.5	80.5	1.1	
		Avg	33.7	81.8		1.2
2000	Panel 15	0	33.8	82.5	1.5	
	East	6	34.3	81.5	1.4	
		12	34.4	81.0	1.3	
		Avg	34.1	81.7		1.4
3000	Panel 8	0	33.9	81.8	1.4	
	East	6	34.1	81.6	1.4	
		12	33.8	81.5	1.3	
		Avg	33.9	81.6		1.4
						1.3

Incl 6

Summary of soil data



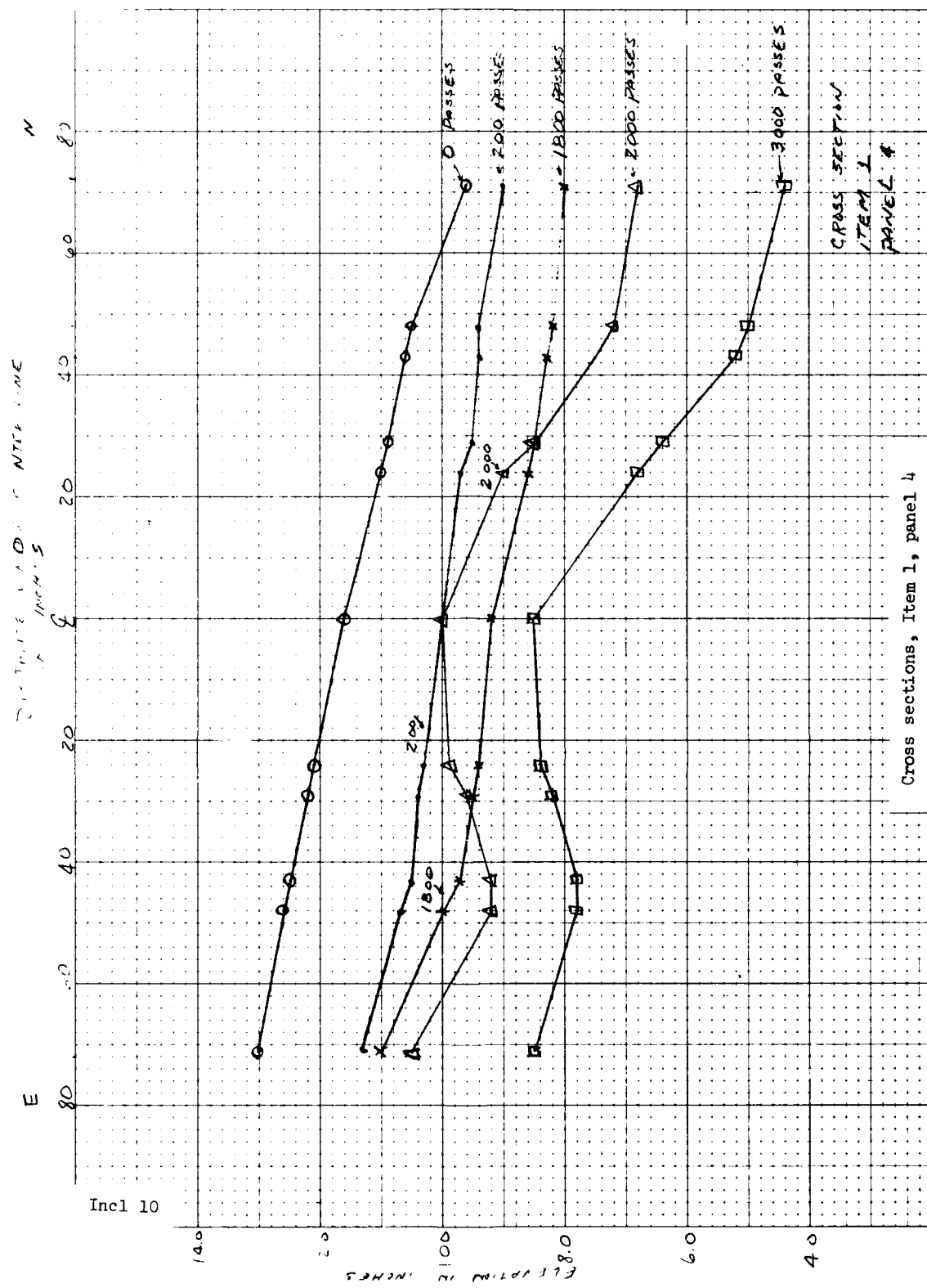
Close-up of welds in item 3

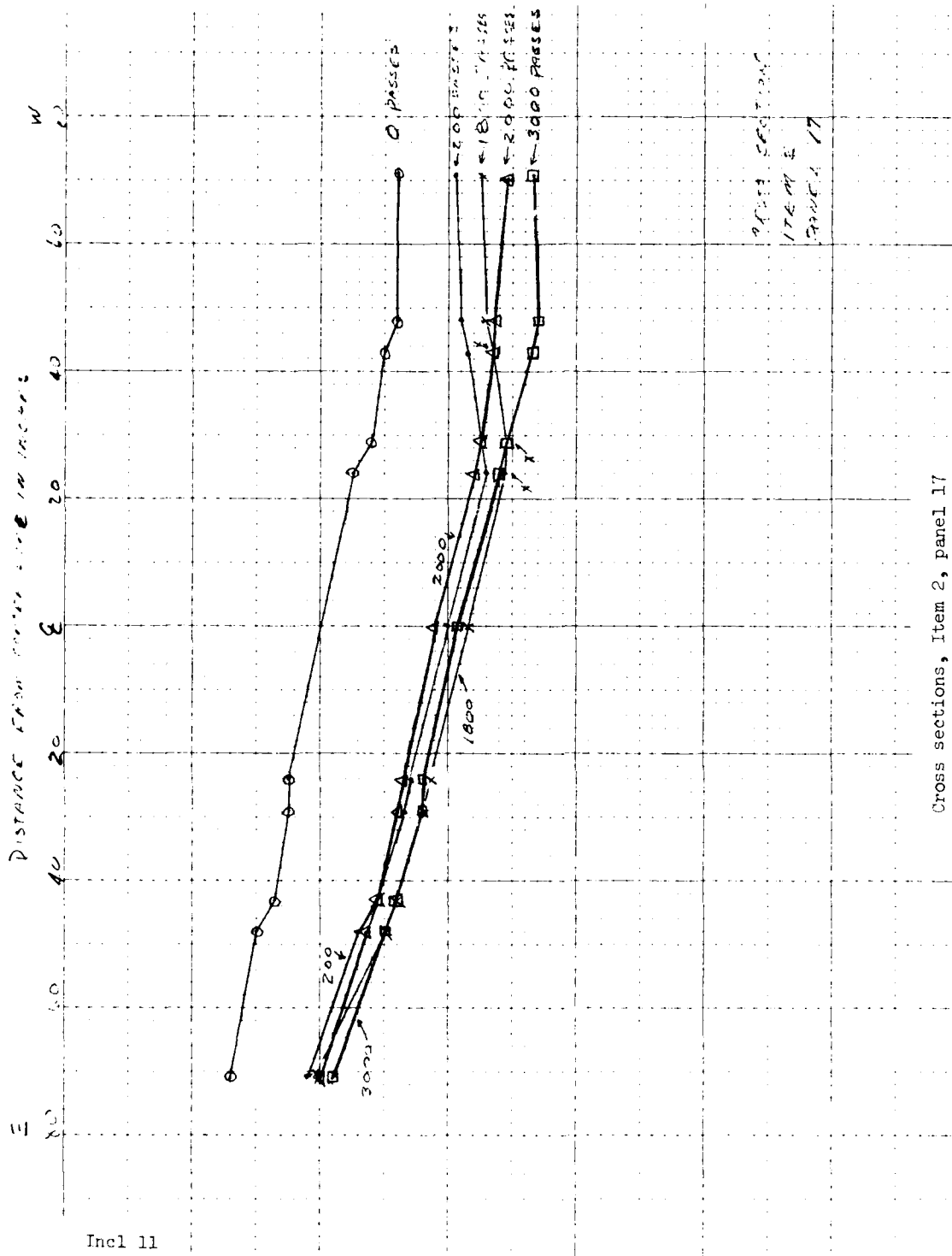
WELDS



General view of the test section, 0 passes

incl 2





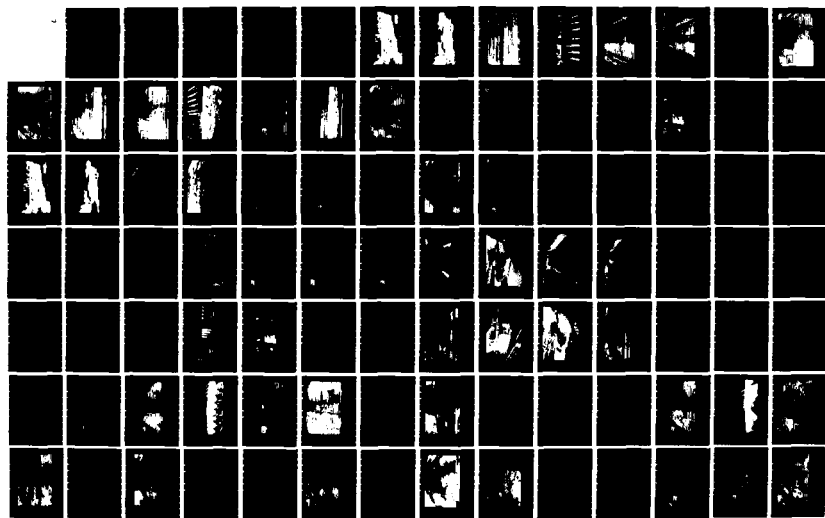
AD-A139 480

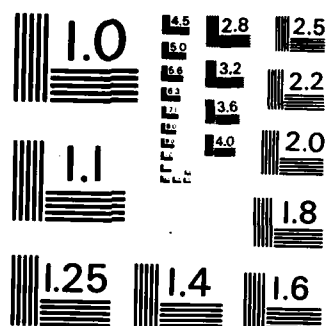
TACTICAL BRIDGE ACCESS//GRESS PRELIMINARY
INVESTIGATIONS(U) ARMY ENGINEER WATERWAYS EXPERIMENT
STATION VICKSBURG MS GEOTECHNICAL LAB B A MATIS SEP 80
F/G 13/2

2/6

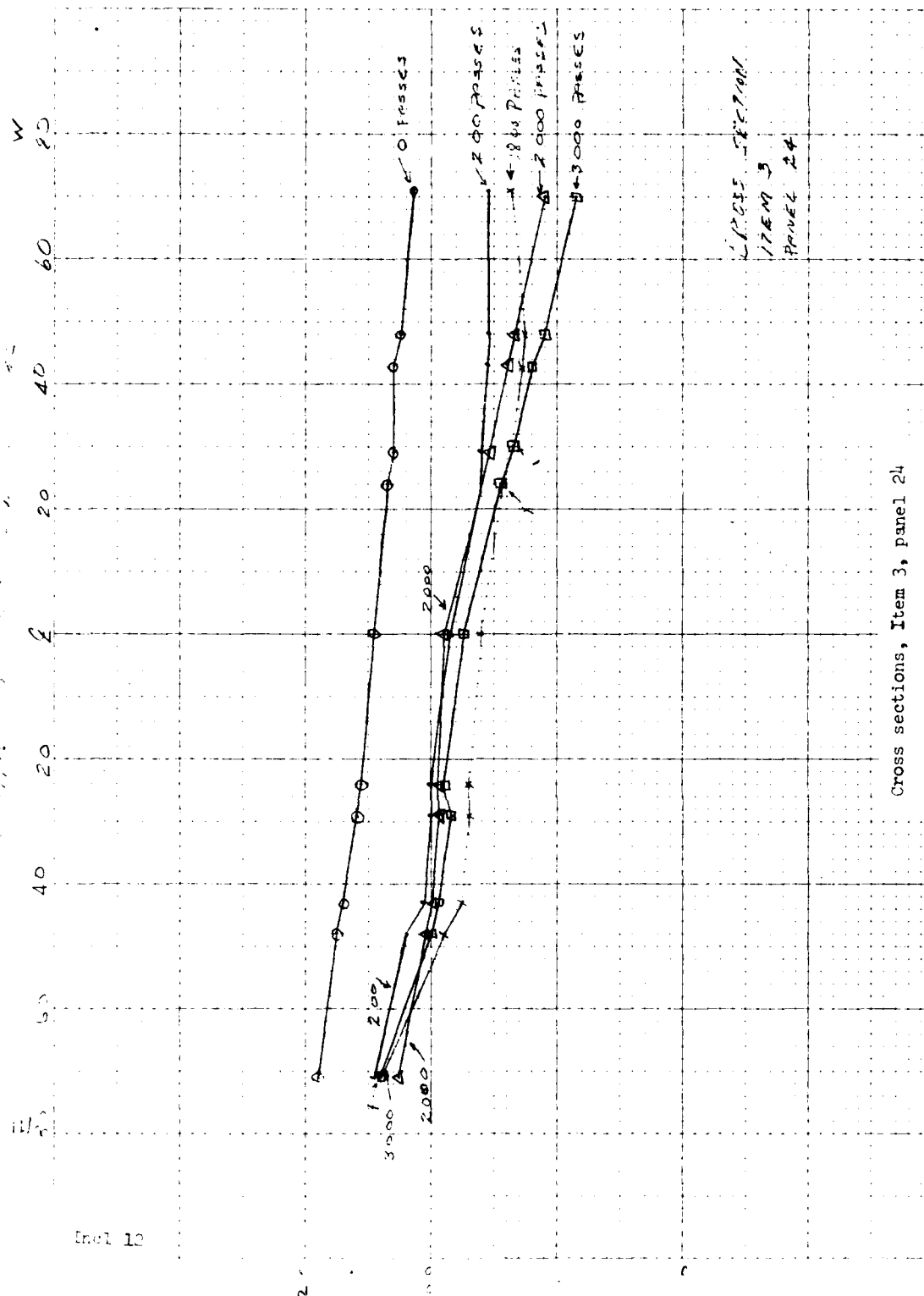
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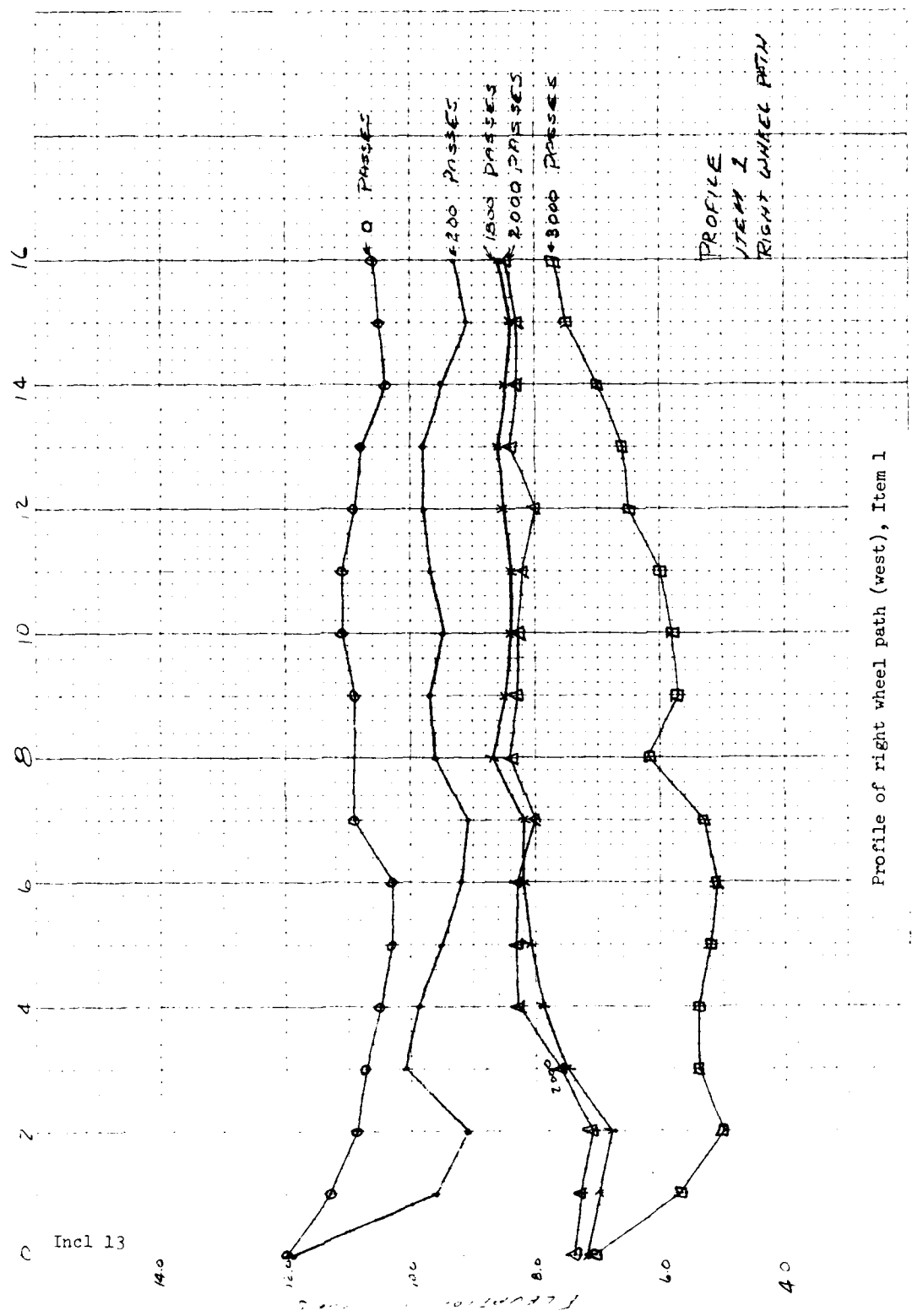
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

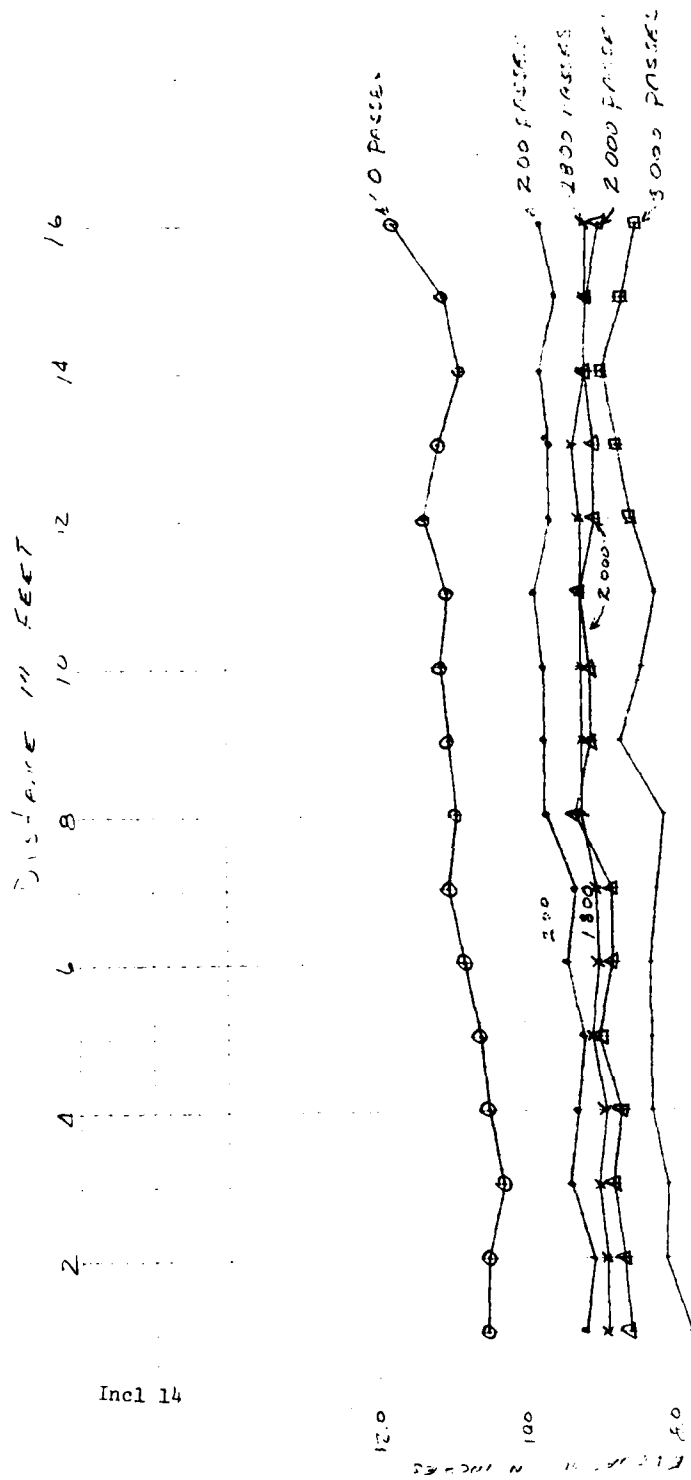


Cross sections, Item 3, panel 24

Incl 12

Profile of right wheel path (west), Item 1



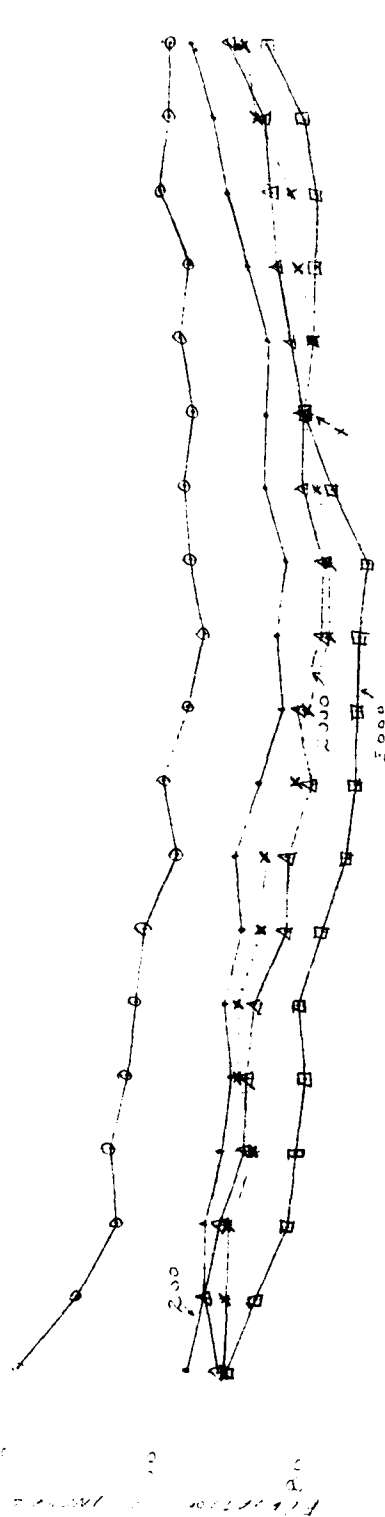


Incl 14

Profile
Item 2
Distance - 10 ft
Scale

Profile of right wheel path (west), Item 2

Incl 15



LEGEND: 0 0 PASSES
 • 200 PASSES
 x 1800 PASSES
 Δ 3000 PASSES
 □ 3000 PASSES

Profile of right wheel path (west), Item 3

Profile of right wheel path (west), Item 3



The 5-ton, M54 cargo truck, gross load, 40,000 lb



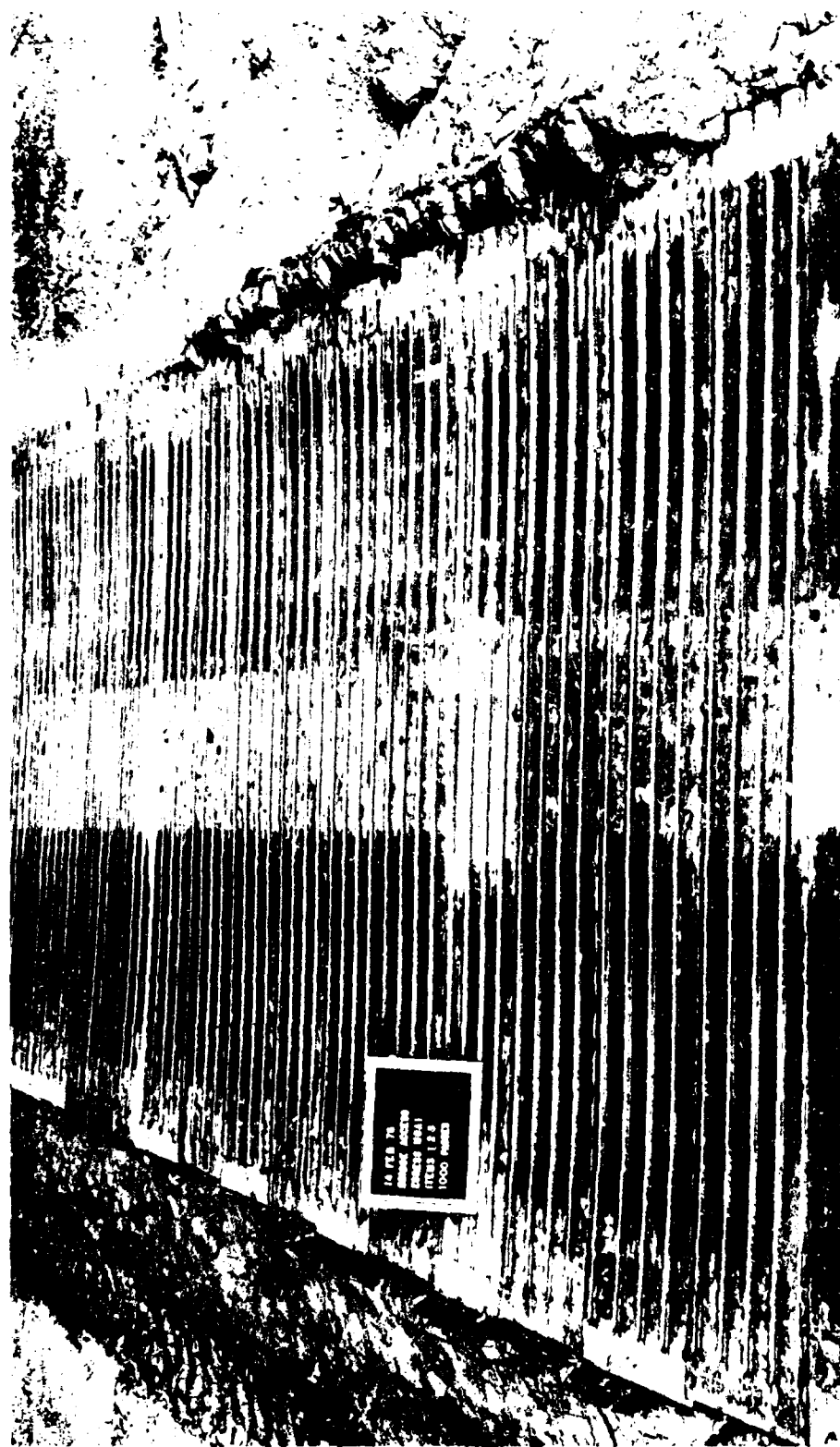
The M48A1 combat tank, gross load, 106,000 lb



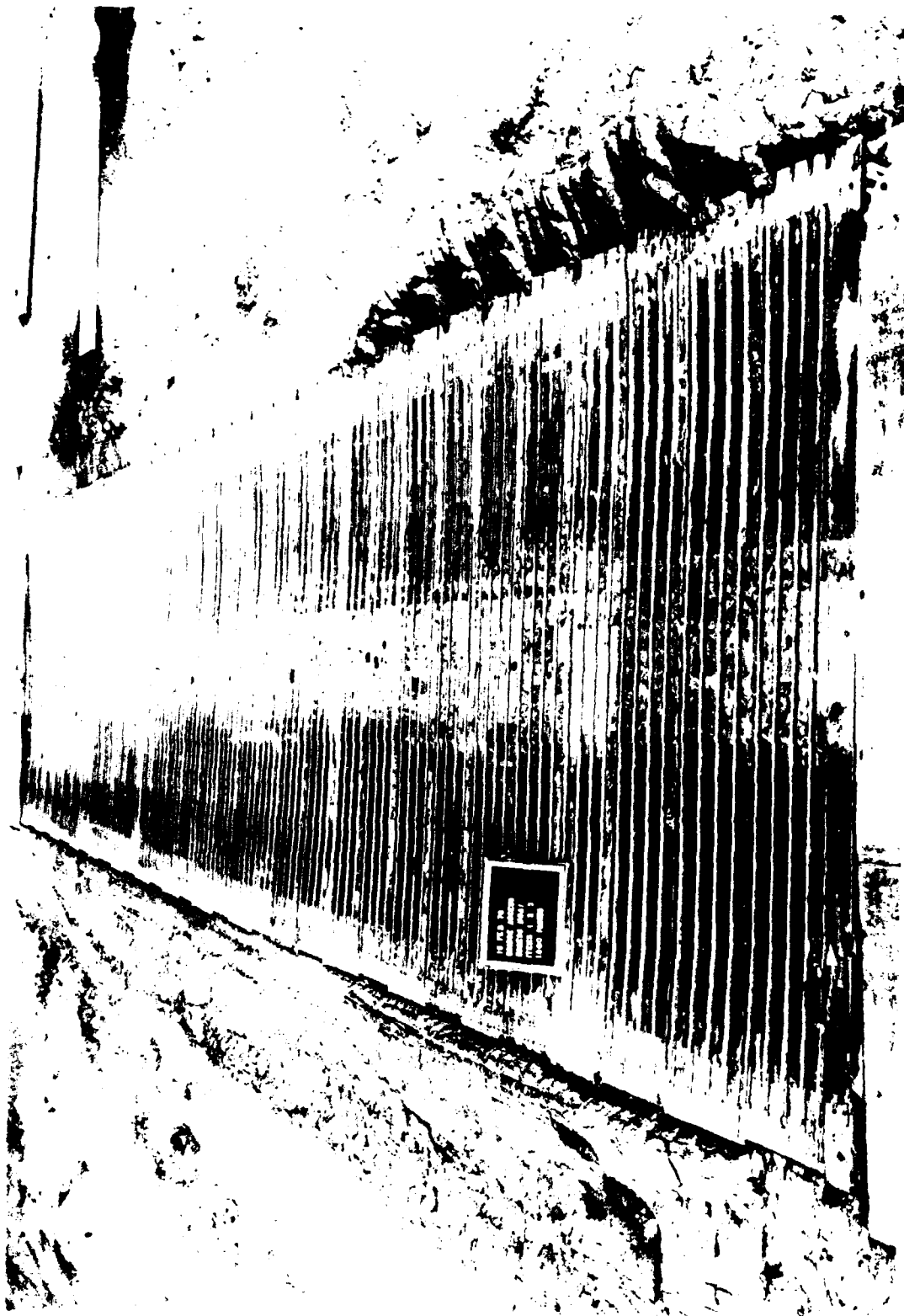
Recessed view, Item 1, 100000

100000





General view of item 1, 1000 parsas. Subgrade along west c/l (right) over 6-in. above
 mat surface.



General view of test section at 1800 passes. Calibrating on what side (right) approximately 100 ft. from test surface.

PERMANENT SET OF PANELS

<u>Item</u>	<u>Panel No.</u>	<u>Deviation from a 12-ft Straightedge, in.</u>			
		<u>Passes</u>	<u>East Rut</u>	<u>Ø</u>	<u>West Rut</u>
1	4	1800	3/4	3/8	5/8
1	4	2000	1-1/4	0	1
1	4	3000	1	0	1-1/4
2	14	1800	1-1/2	1-1/2	1-1/2
2	14	2000	1/2	3/8	1/2
2	14	3000	1/4	0	1/4
3	27	1800	1-1/2	1-3/4	1-3/4
3	27	2000	1	3/4	1
3	27	3000	1/2	1/2	5/8

Permanent set measurements

Incl 22



General view, Item 1, 2000 pages



General view, Item 1, 3000 Pounds



1000000000, 1000000000, 1000000000



16 FEB 78
BRIDGE ACCESS
EDRESS MOAI
ITEM 2
1800 PAGES

5173.57A



Item 2, 2000 passer, mats over 2 in. above embelied runners



Incl. 29

112

General view, Item 3, 0 passes



General view, Item 3, 3000 passes

APPENDIX D

MEMORANDUM FOR RECORD--TRAFFIC TESTS ON M19
LANDING MAT FOR TACTICAL BRIDGE ACCESS/
EGRESS APPLICATIONS



DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESSS

5 July 1978

MEMORANDUM FOR RECORD

SUBJECT: Traffic Tests on M19 Landing Mat for Tactical Bridge Access/Egress Applications

1. During March 1978, accelerated traffic tests were conducted at the WES to determine how the current M19 landing mat inventory item could best be utilized for bridge access/egress applications. The M19 landing mat is a depot stocked item (Federal Stock No. 5680-930-1524) which weighs 4.3 lb per sq ft. The M19 mat is a sandwich-type structure containing an aluminum honeycomb core bonded top and bottom to aluminum skins (Incl 1). The individual panels, 1.5 in. thick, 50-1/4 in. long, and 49-1/2 in. wide, weigh approximately 71 lb.
2. The test section was located under a hangar-type structure to provide protection from the elements. The test section was excavated to a depth of 24 in. below grade and backfilled with a heavy clay. The test section was surfaced with M19 mat placed in three different laying patterns and covered an area 58 ft long and 16 ft wide, and consisted of items 1, 2, and 3 as shown on Incl 2. An approach area was provided at each end of the test section to provide a maneuver area for the test vehicle during the application of traffic. The in-place CBR of the test section prior to traffic was an average of 1.2 for the top 12 in. Soil data are summarized on Incl 3. The item 1 panels were placed in a brickwork pattern with the male-female joints perpendicular to the direction of vehicular traffic and continuous across the test item width (Incl 2). This lay pattern is the standard M19 lay pattern that has been rotated 90 degrees. The panels in item 2 were placed in a brickwork pattern with the overlap-underlap joints perpendicular to the direction of traffic and continuous across the test item width (Incl 2). The standard M19 lay pattern with the male-female joints parallel to the direction of traffic and continuous along the test item length was utilized for placement of item 3 panels (Incl 2).
3. Traffic tests were conducted with a 5-ton military cargo truck and a M48A1 combat tank. The M54 cargo truck (Incl 4) was loaded with a 20,000 lb payload (gross weight, 40,000 lb) and the 11X20, 12-ply tires were inflated to 70 psi. These conditions represented the highway loading for the truck. The M48A1 tank (Incl 5) was loaded with 8000 lb (approximate gross weight, 106,000). Traffic was applied in a channelized pattern similar to that which

WESSS

5 July 1978

SUBJECT: Traffic Tests on M19 Landing Mat for Tactical Bridge Access/Egress Applications

would be encountered in actual road conditions. Mixed traffic was applied with the M54 truck applying 2700 passes and the M48A1 tank applying 300 passes for a grand total of 3000 mixed passes. The sequence of traffic was truck 0 to 1800 passes, tank 1801 to 2000 passes, truck 2001 to 2450 passes, tank 2451 to 2500 passes, truck 2501 to 2950 passes, and tank 2951 to 3000 passes.

4. A view of the overall test section prior to traffic is shown on Incl 6 and a view of items 1, 2, and 3 are shown on Incls 7, 8, and 9, respectively. As the M54 truck moved across the test items, small bow waves were evident on items 1 and 2, however, no movement was noticed on item 3. The continuous joints across items 1 and 2 allowed the runs of mat to move up and down as the truck moved across the mat. After 200 passes, the mat surface remained generally smooth (Incl 10). Runs of mat in items 1 and 2 had moved from east to west approximately 1 in. Identification paint marks were placed along the east edge at each mat joint as shown on Incl 10 in order to measure the lateral mat movement as traffic continued.

5. After 1800 truck passes, no apparent damage had occurred to either of the three test items (Incls 11-13). The maximum lateral movement in item 1 was 4-1/2 in. between runs 3 and 4 and in item 2 was 3 in. between runs 6 and 7. The movement at the transition of items 1 and 2 was 8-1/2 in. No lateral movement had occurred in item 3. At the beginning of traffic, the mat contained a transverse slope from east to west of approximately 3 in. (Incl 14-19). This condition, along with the application of traffic, caused the runs of mat to move laterally. The average maximum change in cross-sections (Incl 14-19) from the beginning to 1800 truck passes on item 1, 2, and 3 were approximately 1.0, 0.9, and 0.7 in., respectively. Profile measurements (Incl 20) indicate less downward mat movement in item 3 than in items 1 and 2.

6. Prior to further traffic testing with the M48A1 tank, all the mat was shifted and straightened such that the panels were in their same approximate position as at the initial start of traffic testing. After 200 passes of the M48A1 tank, the outer edges of the M19 mat in all three test items were pushed down into the subgrade approximately 1-1/2 in. The downward mat movement is shown in the cross section data (Incl 14-19). An overall view of the test section after 2000 total passes is shown on Incl 21. No damage had occurred to the mat and the mat did not shift laterally from east to west due to the tank embedding the mat into the subgrade during traffic. Soft subgrade material was extruded up thru the mat joints at several locations as shown on Incl 21.

7. After 3000 total passes, no damage had occurred to the mat. The outer edges of the mat were pushed down into the subgrade approximately 1-3/4 in. There was a minute change in the cross section and profile measurements from 2000 to 3000 total passes (Incl 14-20). A view of items 1, 2, and

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5 July 1978

SUBJECT: Traffic Tests on M19 Landing Mat for Tactical Bridge Access/Egress Applications

3 at the conclusion of traffic is shown on Incls 22-24; respectively. As the mat was removed from the test section, it was noted that all connectors were filled with soft subgrade material which had entered the connector cavities during traffic.

8. After the mat was removed from the test section, the M48A1 tank was used to traffic the unsurfaced test section which was a 1.3 CBR. The test section prior to traffic is shown on Incl 25. The tank's first pass produced a 3-in. rut in the subgrade (Incl 26) and each successive pass produced a deeper rut. The tank's undercarriage began to touch the subgrade after 9 passes. After 50 passes, the bottom of the tank was dragging the subgrade for the entire length of the test section (Incl 27). The maximum distance from the top of the extruded subgrade along the west edge of the test section to the bottom of the tank track was 30 in. (Incl 28). Due to the tank dragging on the subgrade and thus causing the tank to lose mechanical power, tank traffic was discontinued after 50 passes.

9. Results of this investigation indicated that:

a. All of the test items sustained 3000 passes of the mixed truck and tank traffic and were serviceable for continued traffic.

b. The standard lay pattern (item 3) can be placed easier than the lay pattern of item 2. The item 3 lay pattern is placed such that orientation of the panel's internal honeycomb core is stronger with respect to the direction of traffic than the item 1 lay pattern.

c. From visual observation, there was more bow wave movement in items 1 and 2 than in item 3.

d. The panels in all three test items were in good condition and were suitable for reuse after cleaning mud from the connectors.

e. The M48A1 tank loaded with a gross weight of 106,000 lb can negotiate on a clay subgrade with a CBR of 1.3 for 50 repetitive passes.

10. It is recommended that further traffic tests of M19 mat be conducted on mat panels placed in the standard lay pattern with membrane underlay to determine membrane performance in preventing extrusion of soft subgrade material through mat joints.

Carroll J. Smith

CARROLL J. SMITH

Engineer

Landing Mat Branch

28 Incl

as

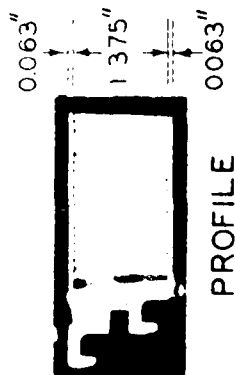
CF w/incl:

DRDME-M

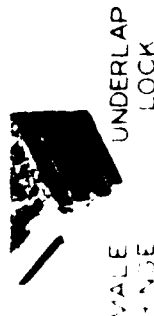
DRDME-MO



CONNECTORS



CONNECTORS



CONNECTORS



CONNECTORS

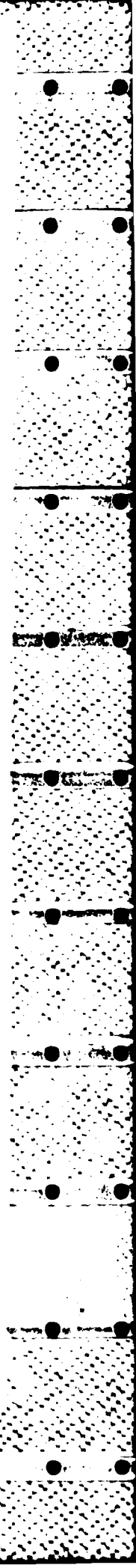
PLAN OF PANEL

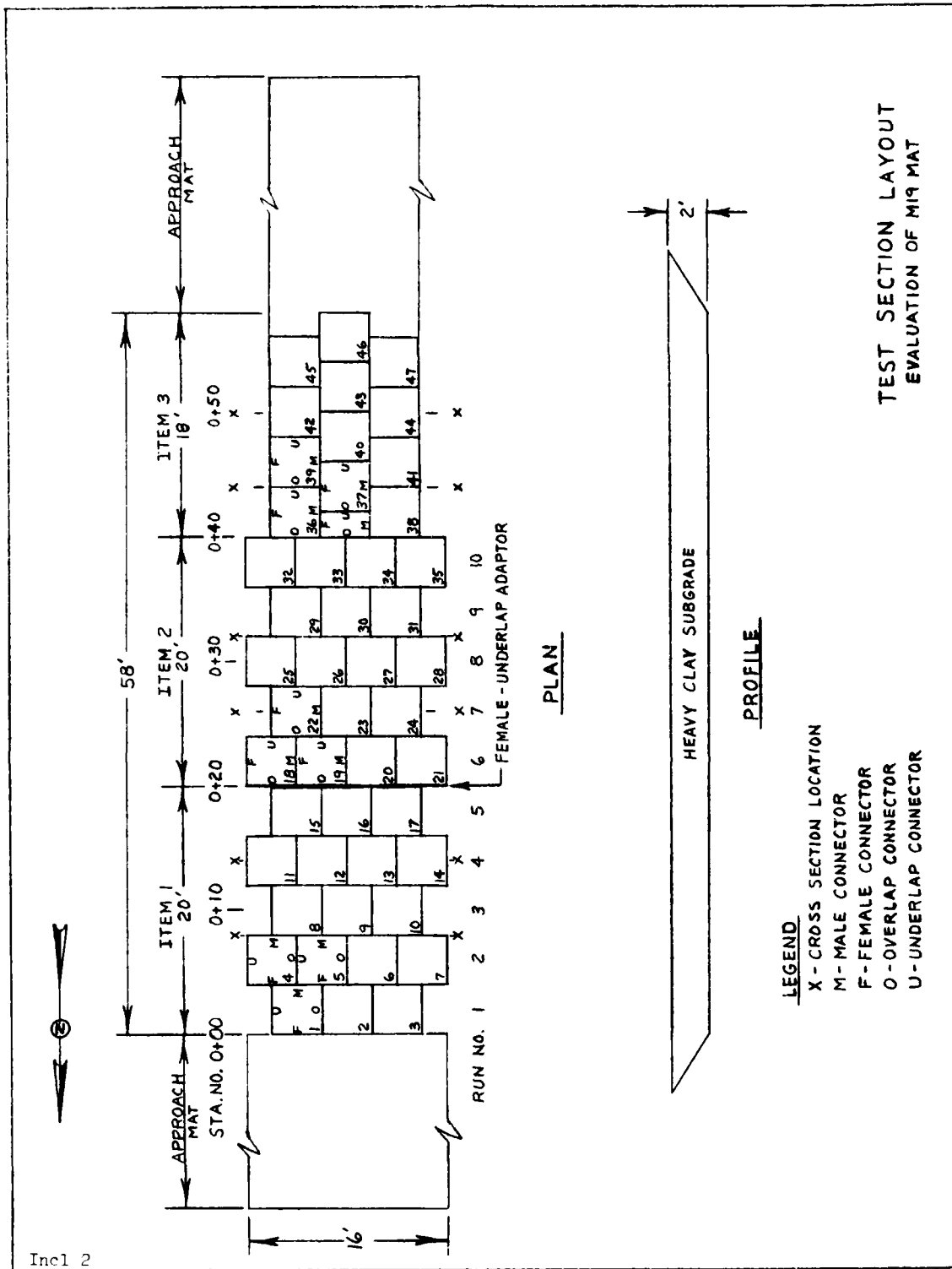
NOMINAL DIMENSIONS

3'-2 1/4" x 4'-1 1/2"

AIRPLANE LANDING MAT, ALUMINUM,
SANDWICH TYPE, XM19

Top view of XM19 aluminum landing mat

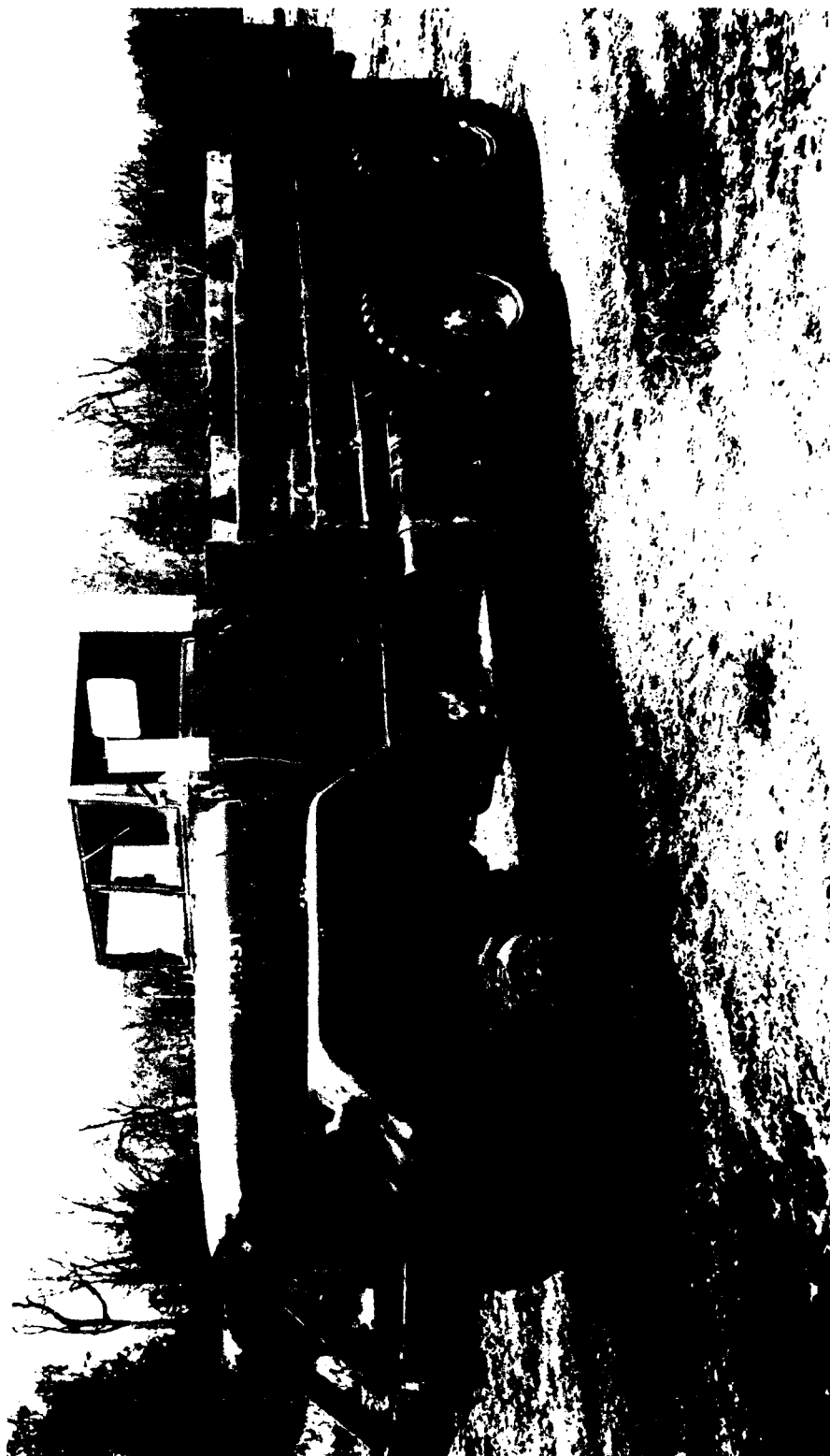




SUMMARY OF WATER CONTENT, DRY DENSITY, AND CBR DATA

NUMBER OF PASSES	LOCATION	DEPTH IN.	WATER CONTENT %	DRY DENSITY PCF	CBR
0	STA. 0+30 (CENTERLINE OF SECTION)	0	35.0	80.4	1.1
		6	35.1	80.6	1.2
		12	34.4	81.1	1.2
		AVG	34.8	80.7	1.2
3000	STA 0+30 (4' WEST CENTERLINE)	0	35.3	82.2	1.1
		6	34.2	82.0	1.2
		12	31.9	84.0	1.5
		AVG	33.8	82.7	1.3

Incl 3

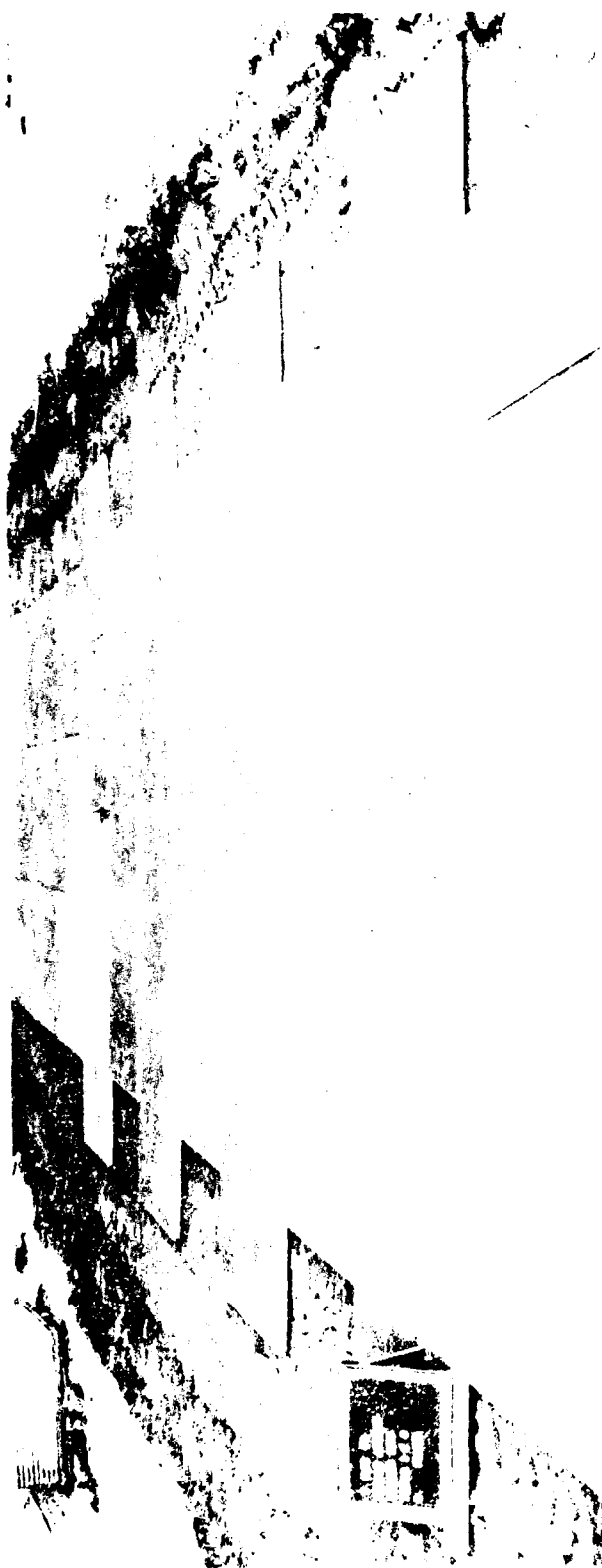


View of truck, 1954, gross weight, 40,000 lb.

Incl 4



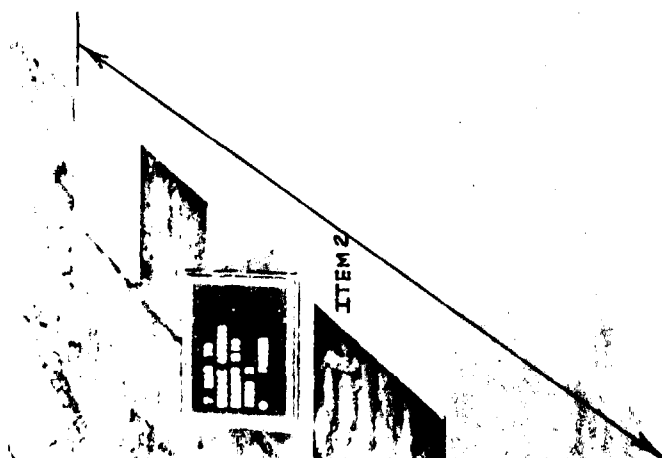
View of M48A1 Combat Tank loaded to 2000 lb (gross weight), 10,000 lb



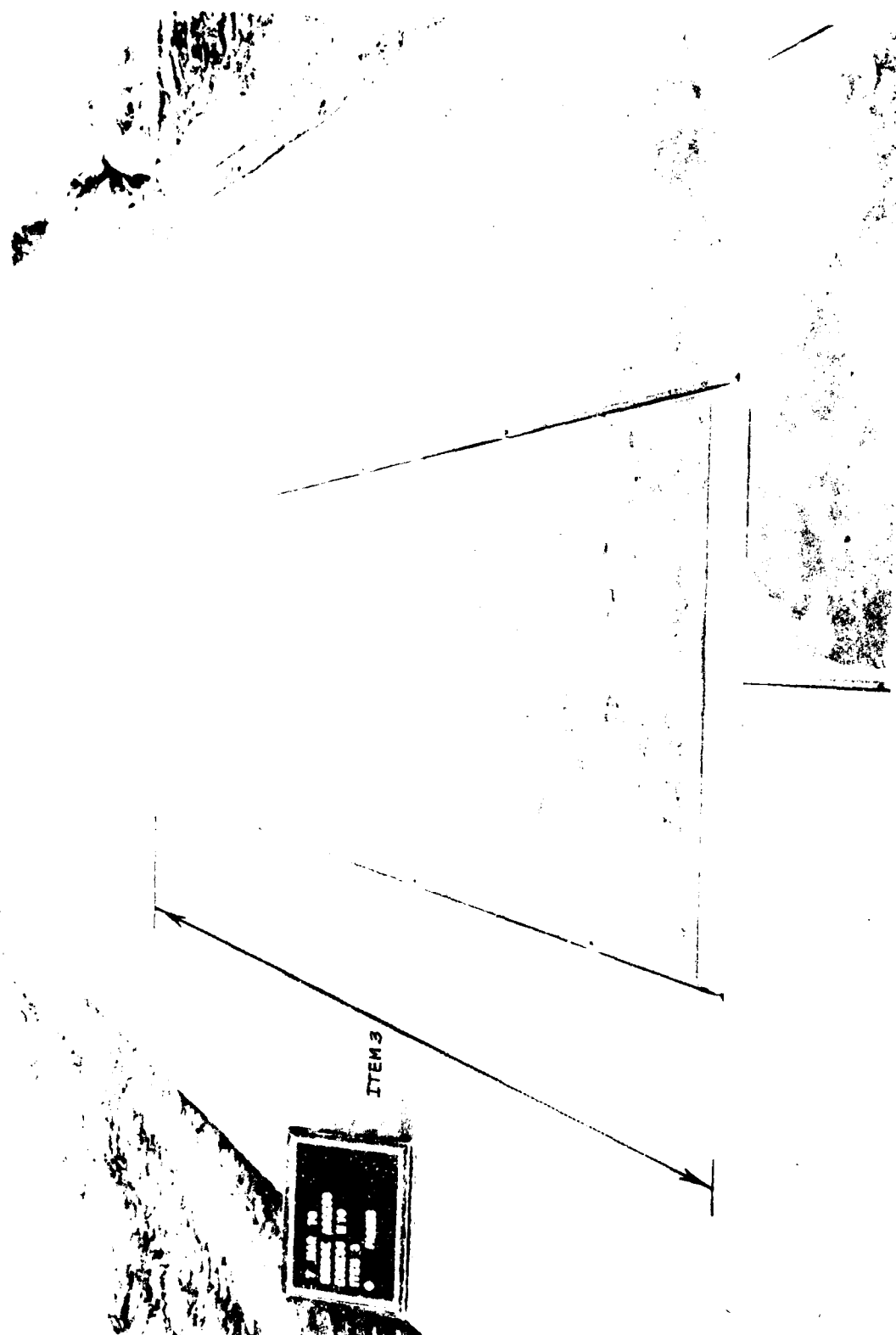


Item 1 prior to traffic

Incl 7



ITEM 2

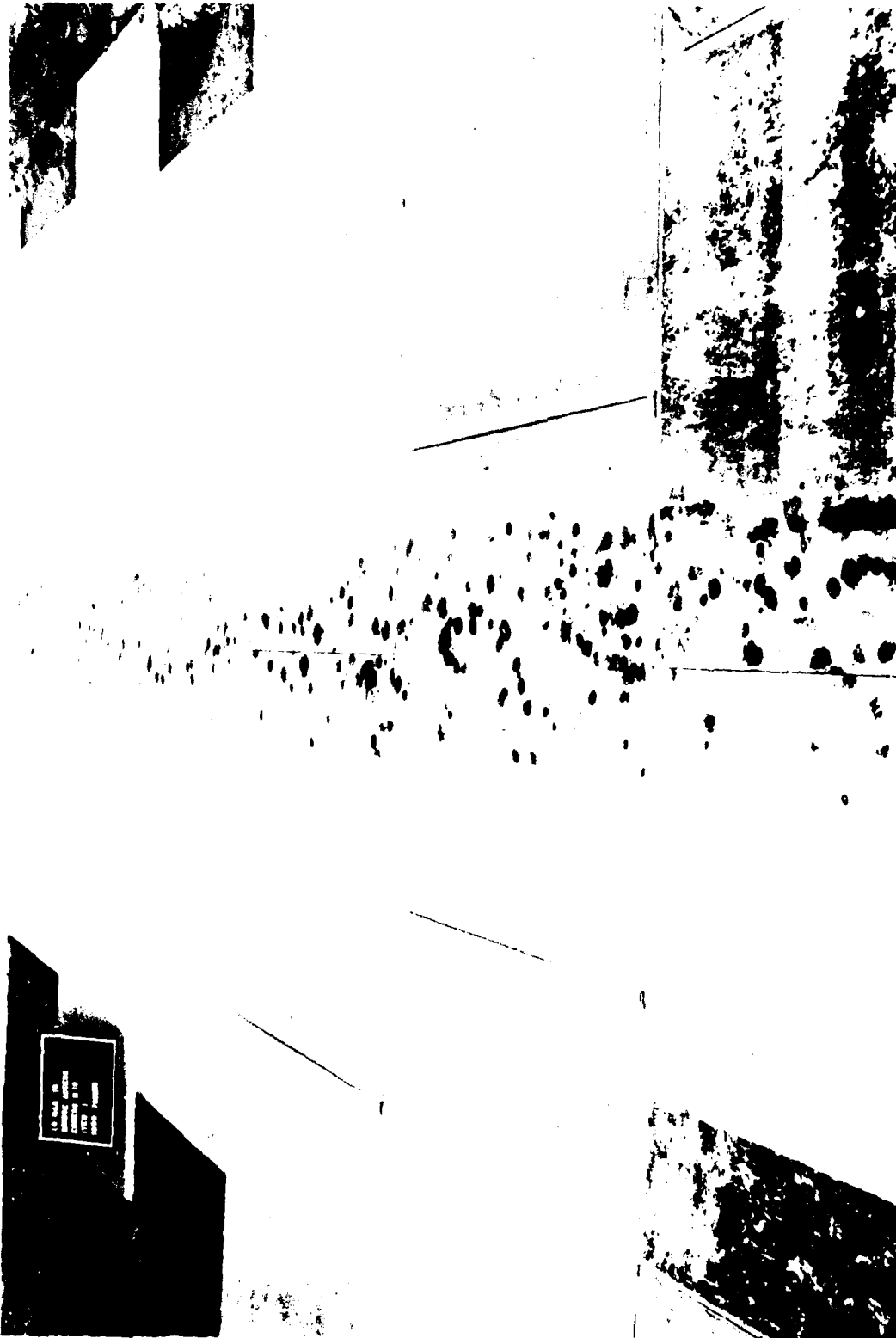


Item 3 prior to traffic

Fig. 10

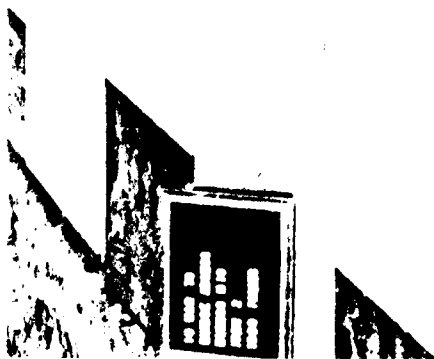
127

Not available after 300 truck passes



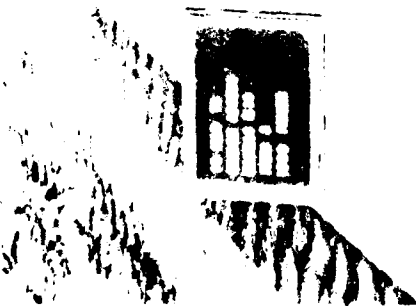
Item 1 after 1300 truck passes

Inc 21



Incl. 10

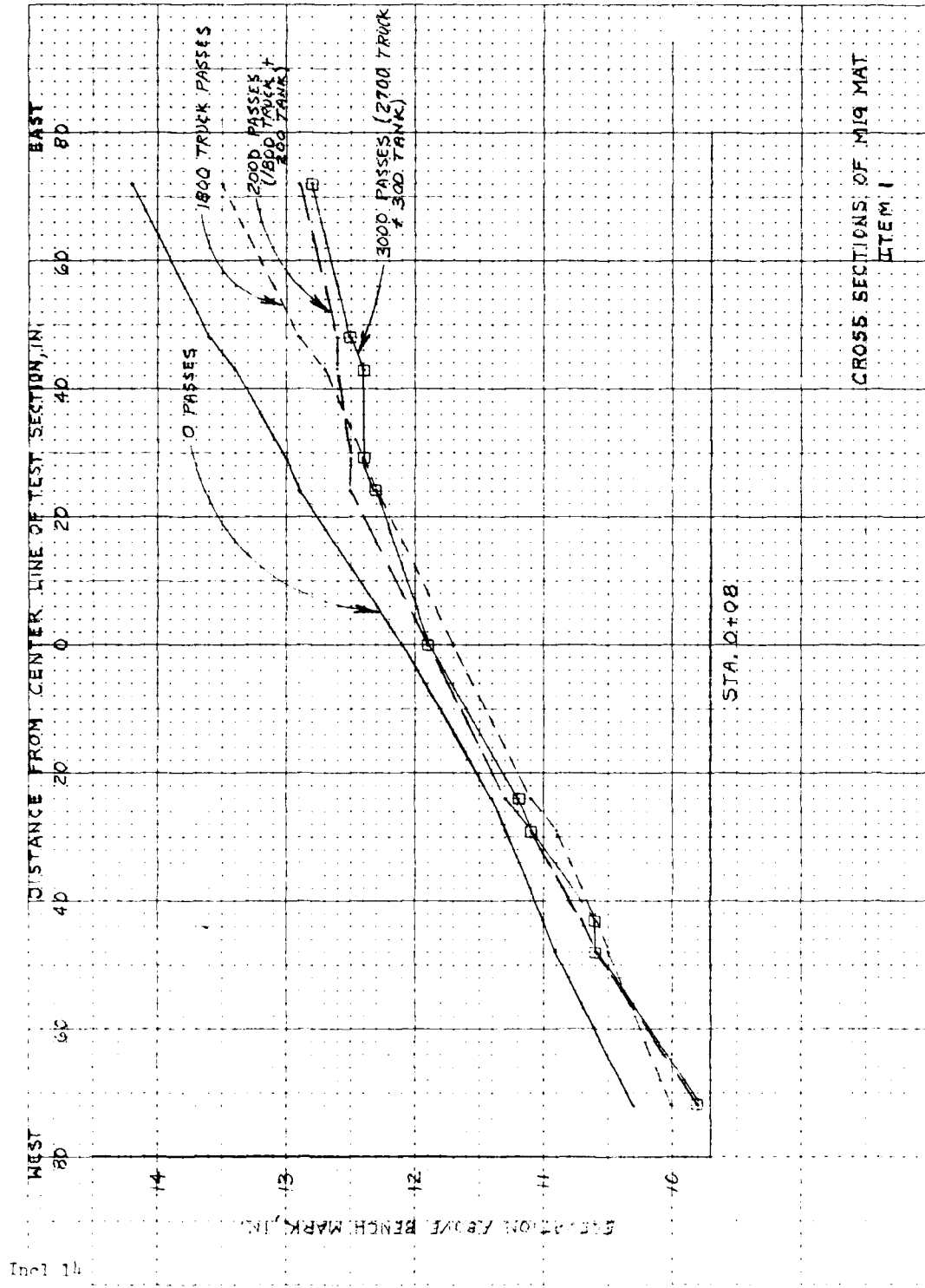
Item 2 after 1800 truck passes



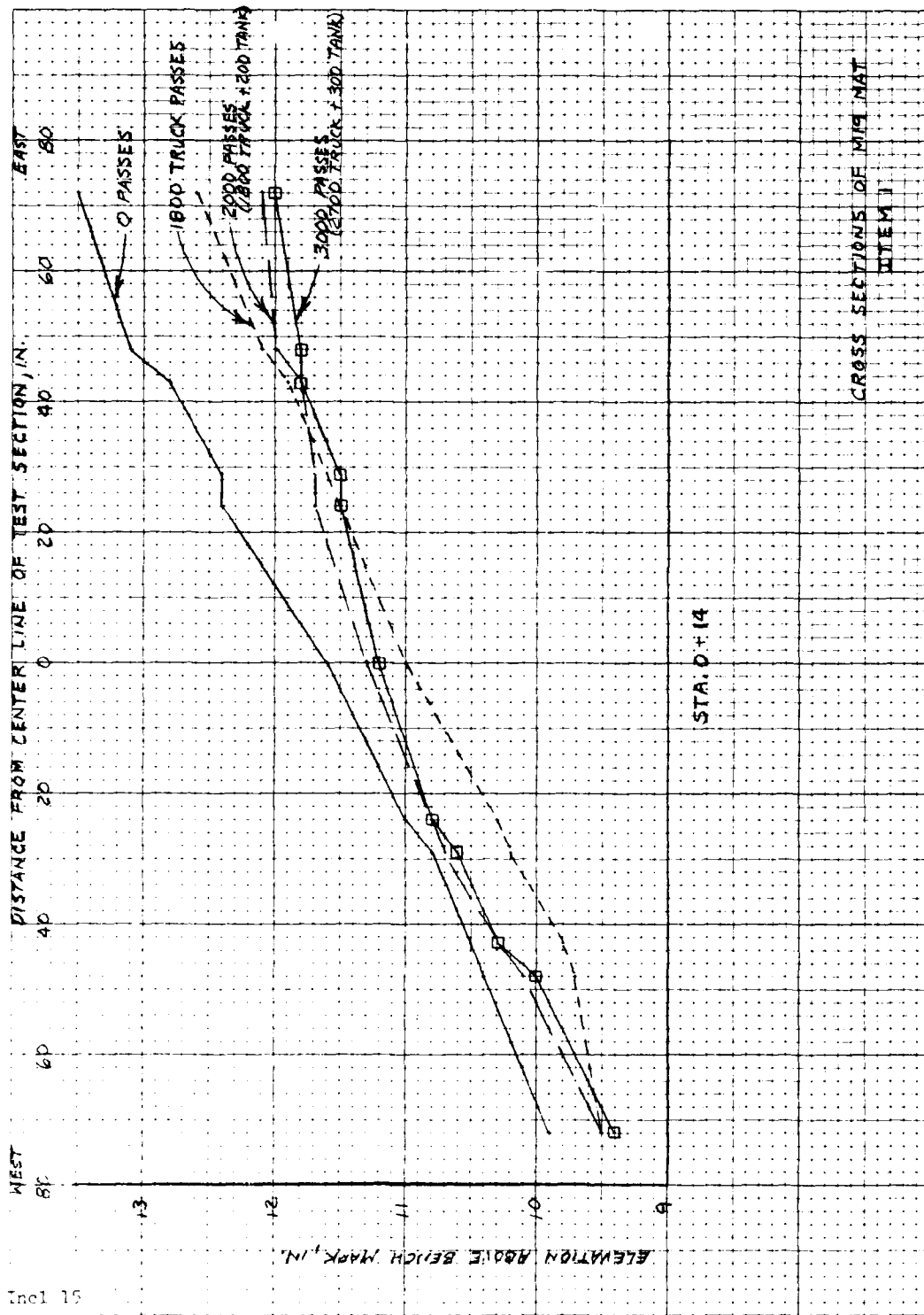
In-1 13

130

Item 3 after 1800 truck passes

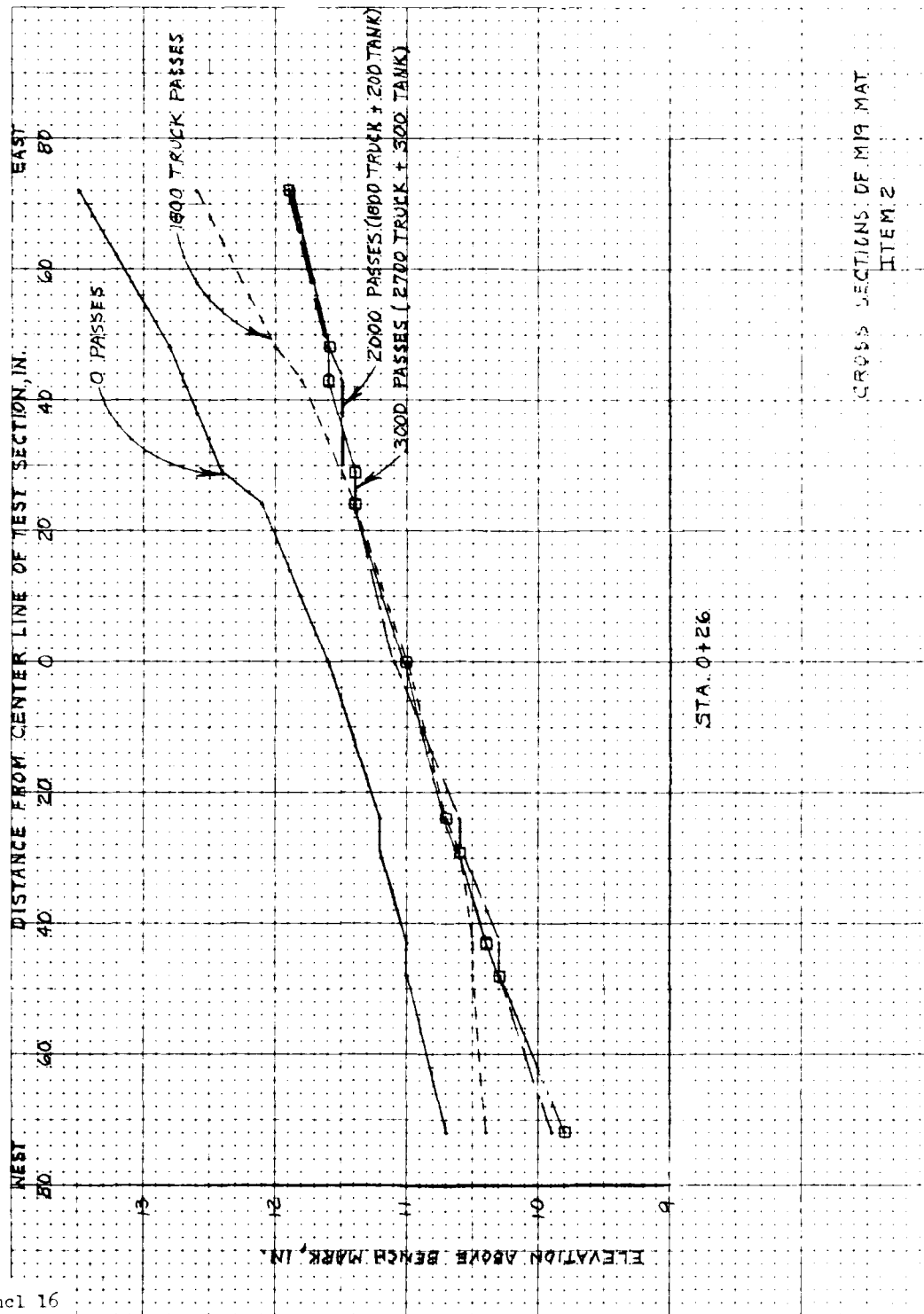


Incl 14



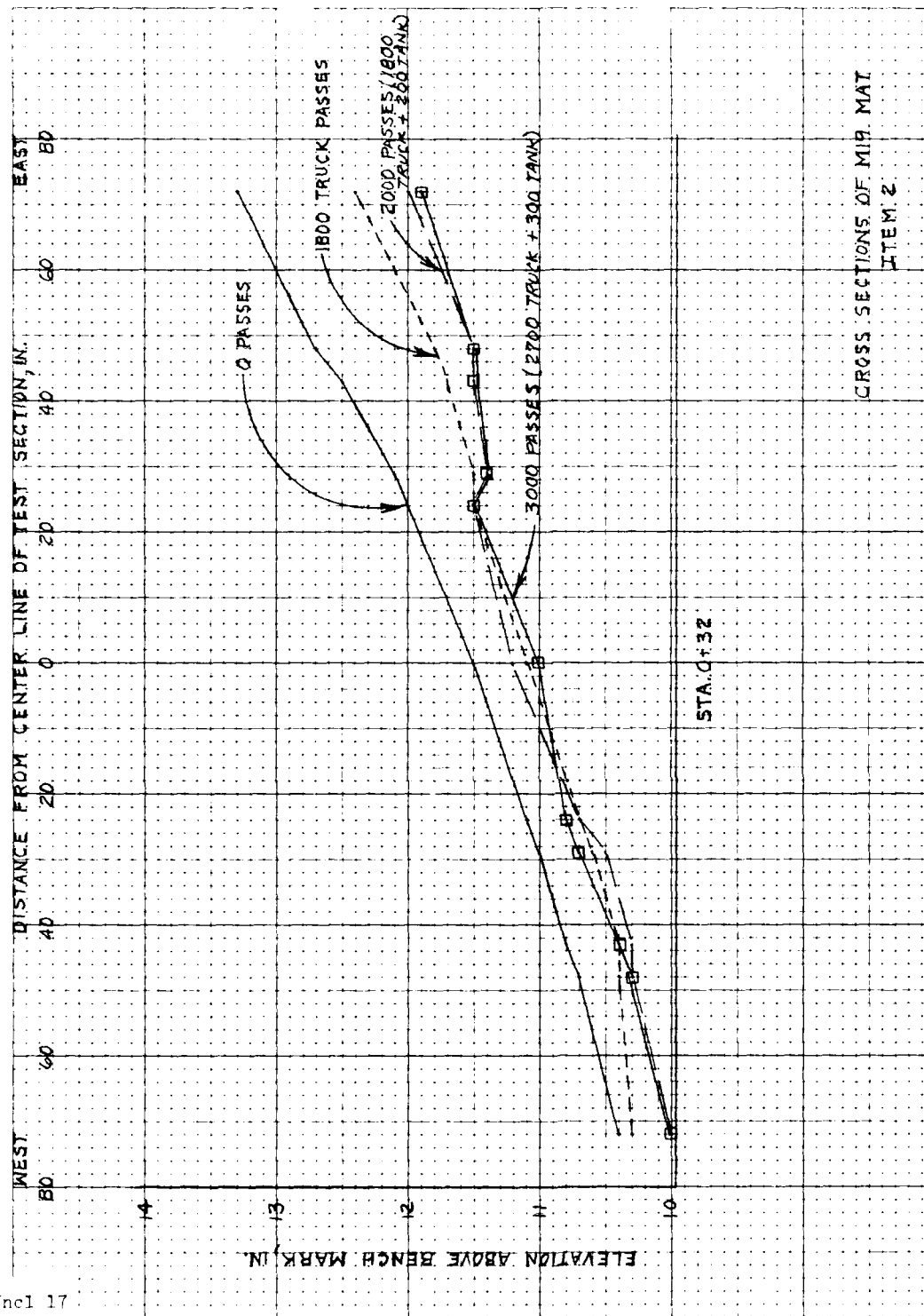
Incl 15

Incl 16

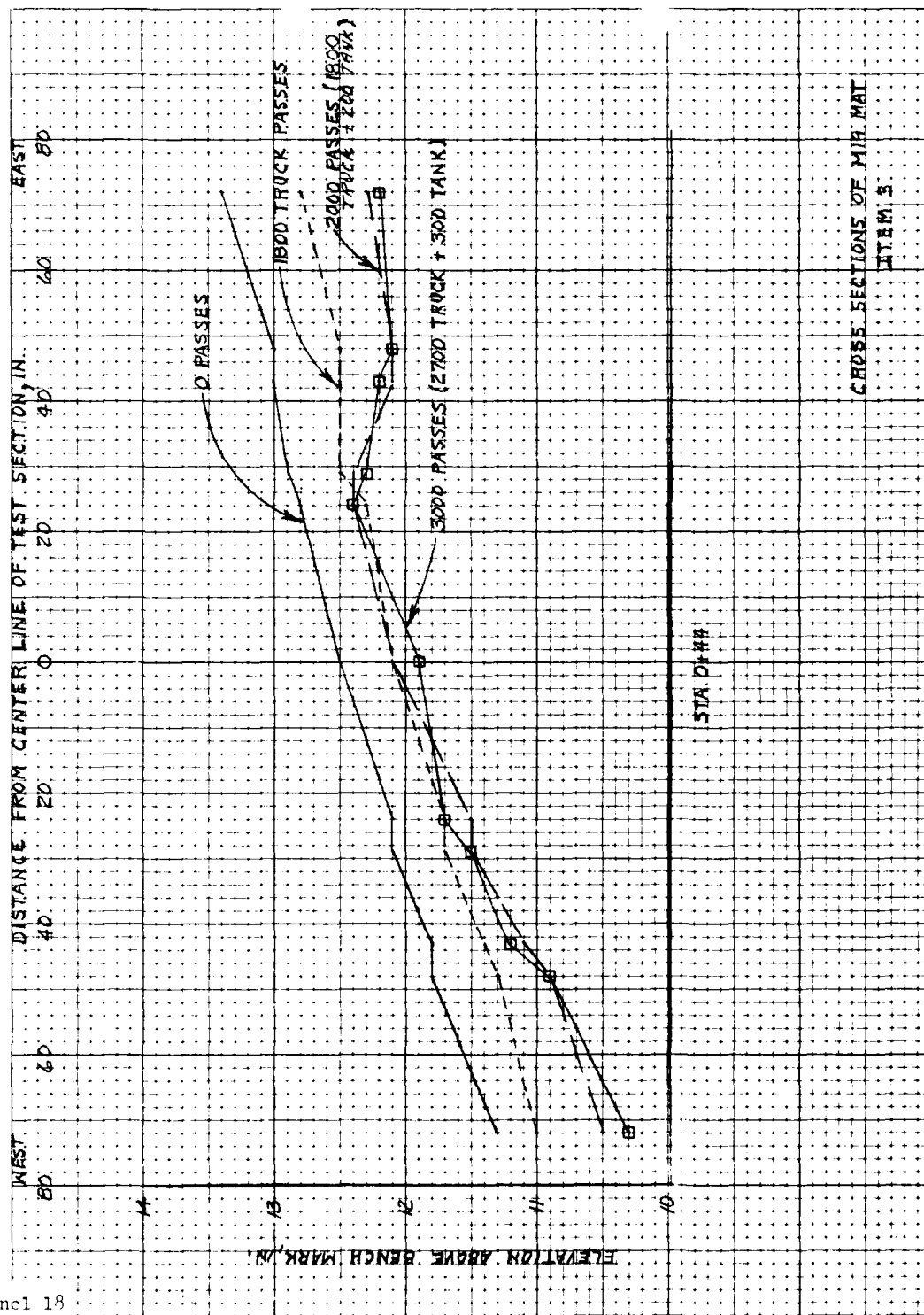


CROSS SECTIONS OF M19 MAT
ITEM 2

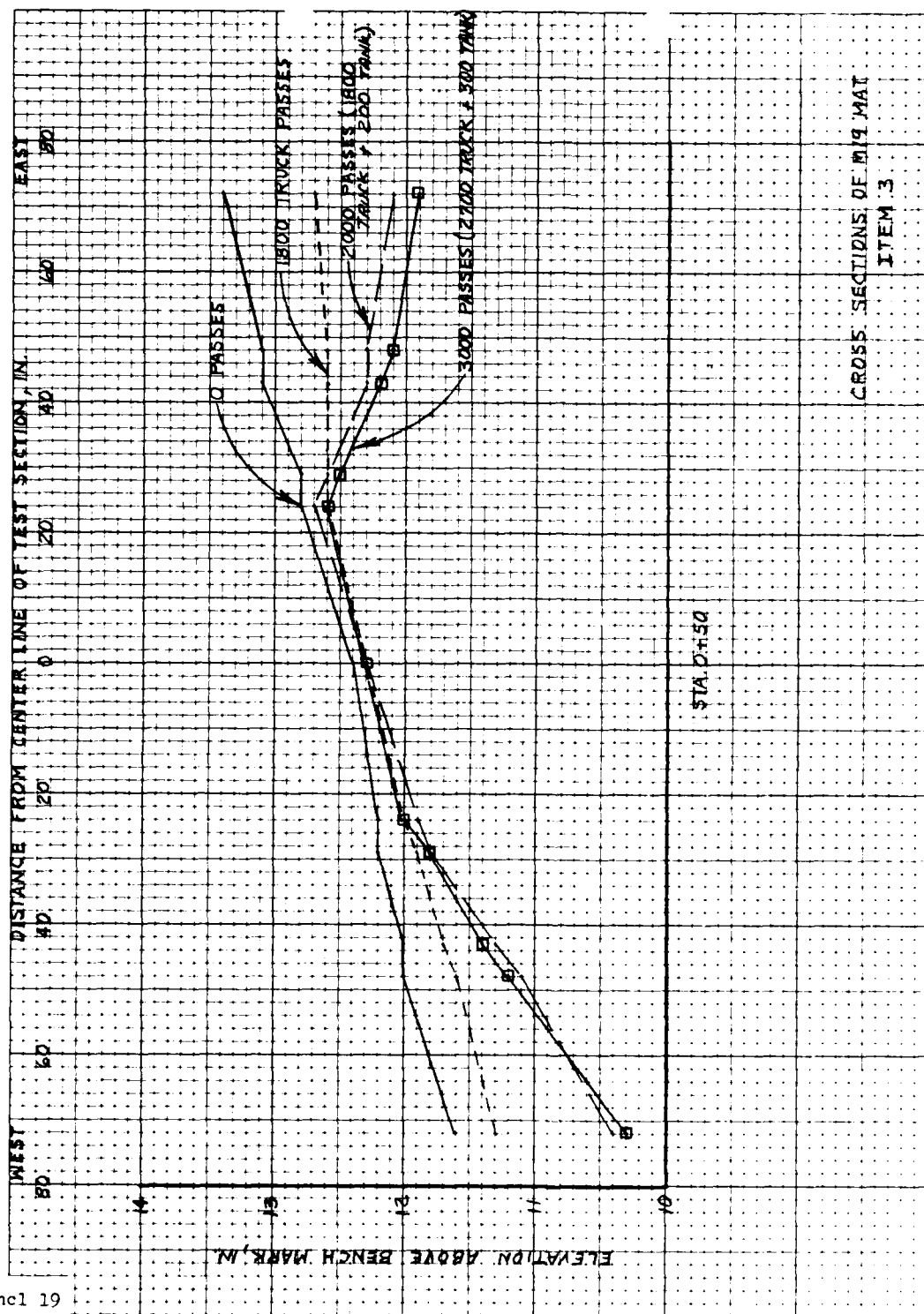
Incl 17

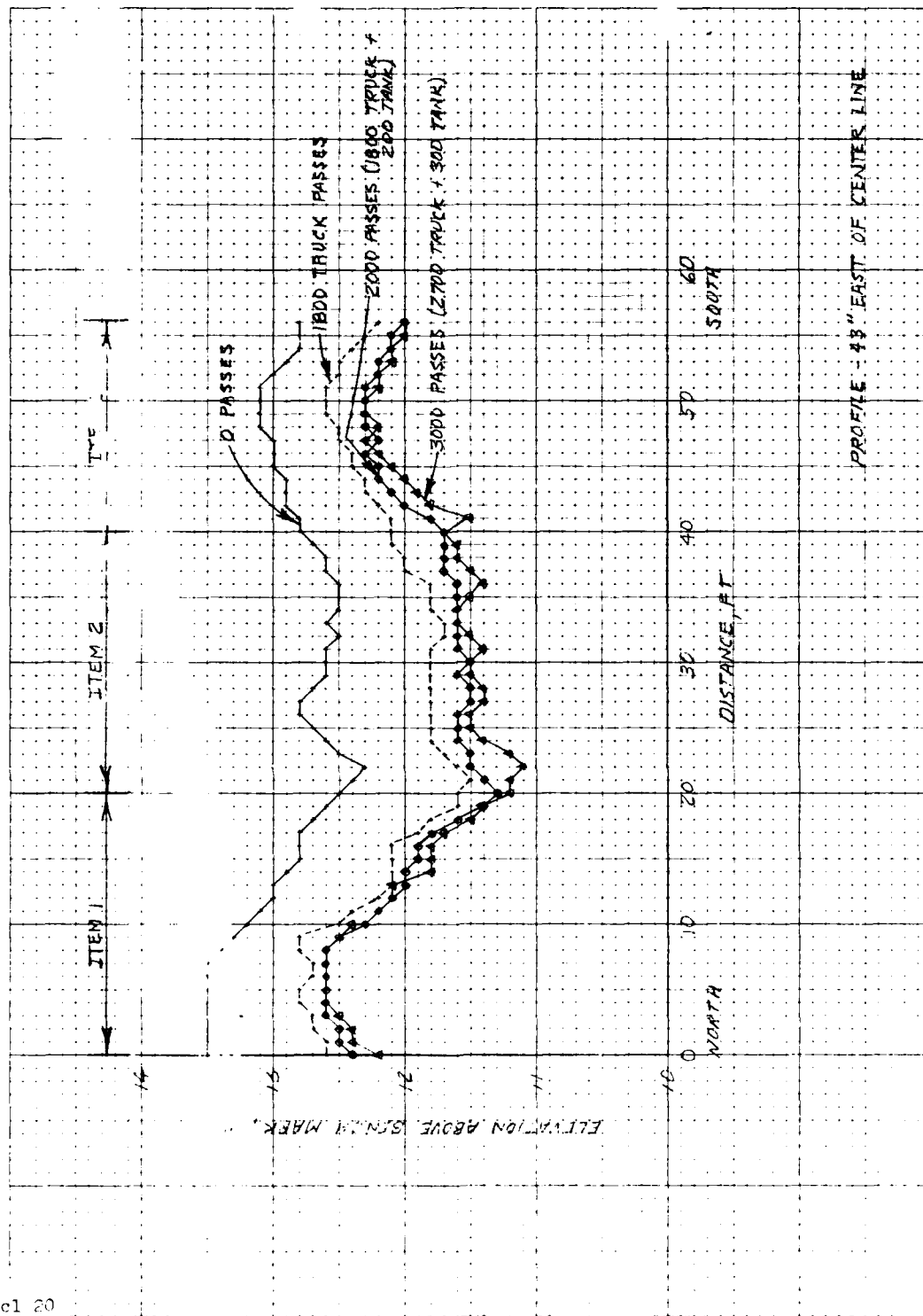


Incl 18

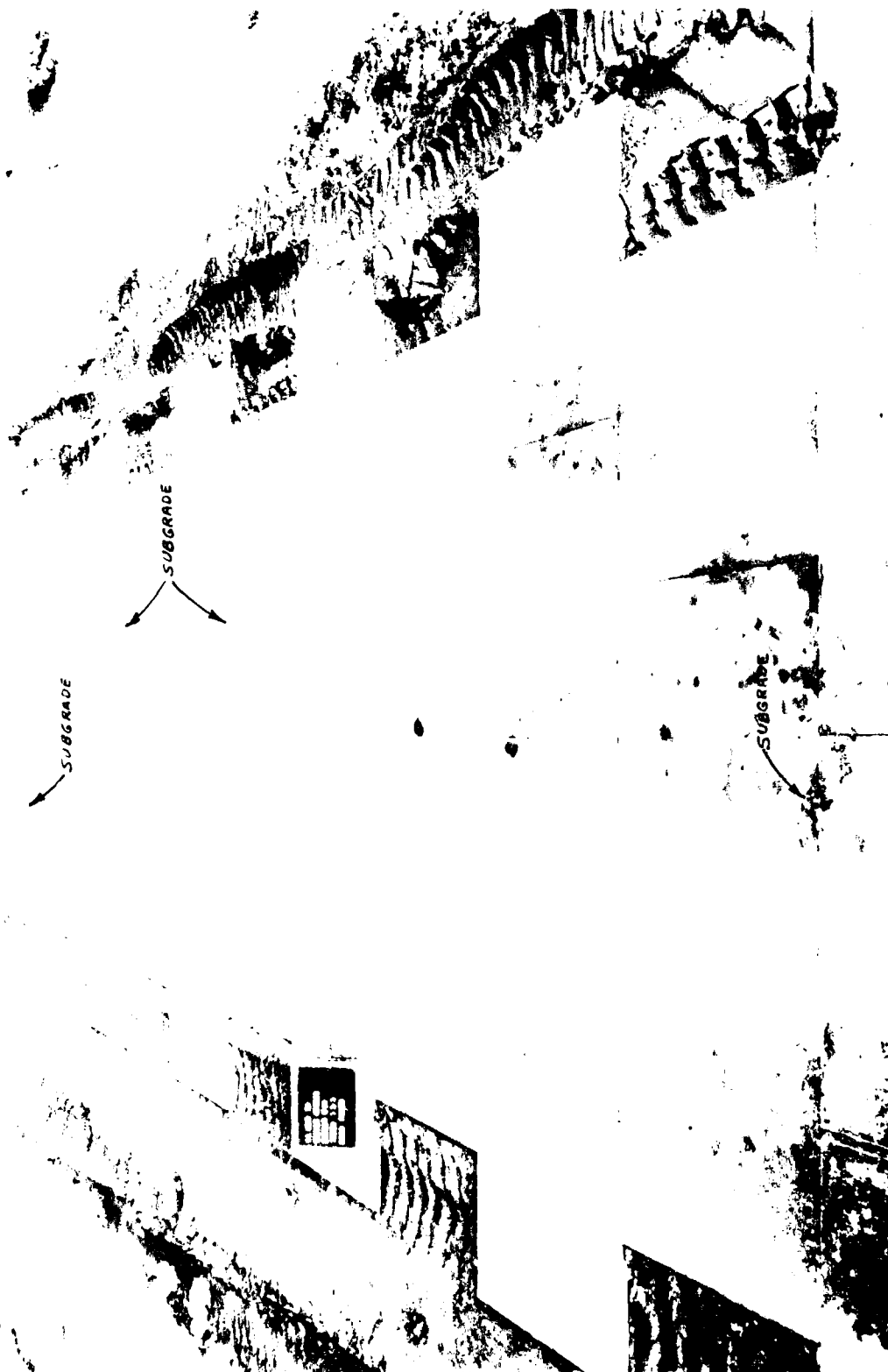


Incl 19





Incl 20



General view of the section after 2000 total passes

Incl. 01



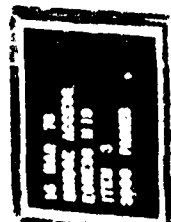
Item 1 after 3000 total passes



14. MAP IN
HOMER ADDRESS
ENCLOSURE WITH
ITEM 2
1000 PAGES

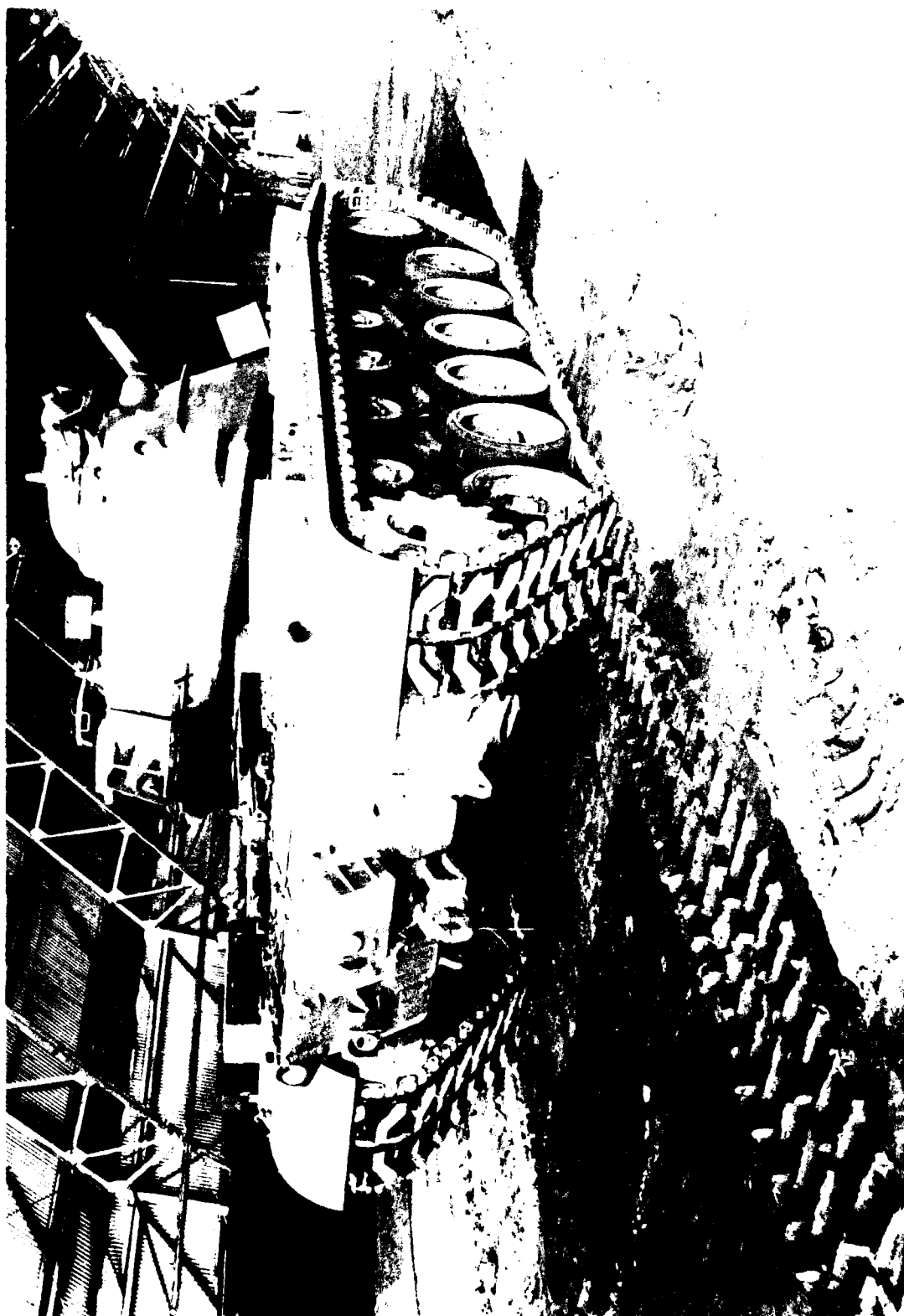
Item 2 after 3000 total passes

Item 3 after 3000 total passes





View of test section after the mat was removed





Tank on test section after 50 passes



View of 30 in. subgrade differential after 50 passes of M-8A1 tank

APPENDIX E

MEMORANDUM FOR RECORD--TRAFFIC TESTS ON M8A1 AND
M19 LANDING MATS WITH AND WITHOUT T17 MEMBRANE
UNDERLAY FOR TACTICAL BRIDGE ACCESS/
EGRESS APPLICATIONS



DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO WESGS

4 October 1973

MEMORANDUM FOR RECORD

SUBJECT: Traffic Tests on M8A1 and M19 Landing Mats With and Without
T17 Membrane Underlay for Tactical Bridge Access/Egress
Applications

1. During the period April-May 1978, accelerated traffic tests were conducted at the WES on M8A1 and M19 landing mats placed with and without T17 membrane underlay for the purpose of determining how these current inventory items could best be utilized for bridge access/egress applications. The M8A1 steel landing mat panel (Incl 1) is approximately 12 ft long by 19 in. wide and 1 in. thick and weighs 144 lb or 7.5 lb per sq ft. The panels were fabricated from 0.125-in.-thick sheet material, rolled, and formed into ribbed panels. The M19 landing mat is a sandwich-type structure containing an aluminum honeycomb core bonded top and bottom to aluminum skins (Incl 2). The individual panels, 1.5 in. thick, 50-1/4 in. long, and 49-1/2 in. wide, weigh approximately 71 lb or 4.3 lb per sq ft. The T17 membrane is a depot-stocked item which weighs approximately 0.33 lb per sq ft. The T17 membrane is a two-ply, neoprene-coated nylon material which was prefabricated in sections 36 ft wide and 100 ft long and is designed as a waterproofing material for airfield surfacings.

2. The test section used in these investigations was located under a hangar-type structure to provide protection from the elements. The test section was excavated to a depth of 24 in. below grade and backfilled with a heavy clay. It covered an area 82 ft long and 18 ft wide and consisted of items 1, 2, 3, and 4 as shown on Incl 3. An approach area was provided at each end of the test section to provide a maneuver area for the test vehicle during the application of traffic. The in-place CBR of the test section prior to traffic was an average of 1.2 for the top 12 in. Soil data are summarized on Incl 4. The T17 membrane was first placed on the subgrade of items 2 and 3 and M8A1 and M19 mats were then laid on the test section and connected with an H-connector at their juncture (Incl 3). The M8A1 panels were placed on items 1 and 2 in a brickwork pattern (Incl 3) such that adjacent sides were joined by connectors consisting of bayonets and slots (Incl 1). The end connectors were joined by sliding the four end connector bars into receiving slots and bending the cover-plate tabs down. The M19 panels were placed on items 3 and 4 in a normal brickwork pattern with the male-female

WESGS

4 October 1973

SUBJECT: Traffic Tests on M8A1 and M19 Landing Mats With and Without
T17 Membrane Underlay for Tactical Bridge Access/Egress
Applications

joints parallel to the direction of vehicular traffic and continuous along the length of the test section (Incl 3). A general view of the test section prior to traffic is shown on Incl 5.

3. Traffic tests were conducted with a 5-ton military dump truck and an M48A1 combat tank. The M51 dump truck (Incl 6) was loaded with a 20,000-lb payload (gross weight, 40,000 lb) and the 11X20, 12-ply tires were inflated to 70 psi. These conditions represented the highway loading for the truck. The M48A1 tank (Incl 7) was loaded with 8000 lb (approximate gross weight, 106,000 lb). Traffic was applied in a channelized pattern similar to that which would be encountered in actual road conditions. Mixed traffic was used with the M51 truck applying 2700 passes and the M48A1 tank applying 300 passes for a grand total of 3000 mixed passes. The sequence of traffic was truck 0 to 1800 passes, tank 1801 to 2000 passes, truck 2001 to 2450 passes, tank 2451 to 2500 passes, truck 2501 to 2950 passes, and tank 2951 to 3000 passes.

4. Item 1, traffic test (M8A1 mat - no membrane underlay). Prior to traffic, the mat surface was generally smooth (Incl 8). During the initial truck passes, panels were forced down and deformed by traffic causing some subgrade material to be extruded up onto the mat surface through the connector and locking lug slots. After 200 passes, the mat surface was an average of 2 in. lower (Incls 9-11) than at the beginning of traffic. The panels were deformed along the truck wheel paths, and measurements (Incl 12) indicated a maximum change of 3-1/4 in. from an 18-ft string line stretched across the width of the test section. The east edge of the mat was approximately 3 in. above the underlying subgrade. A view of item 1 after 200 passes of the M51 dump truck is shown on Incl 13.

5. As traffic continued, the deformation along the truck wheel paths increased and subgrade material continued to be extruded up onto the mat surface; however, the mat remained in good condition and performed satisfactorily through 1800 truck passes (Incl 14). The maximum change in both cross-section (Incls 9 and 10) and profile (Incl 11) measurements from the beginning of traffic to 1800 passes of the M51 truck was 2.7 and 3.0 in. The permanent set measurements (Incl 12) indicated a maximum change of 5 in. in item 1 after 1800 passes. The east edge of the deformed mat was approximately 4-1/2 in. above the underlying subgrade.

6. The M48A1 tank tracked the section for the next 200 passes (1801 to 2000 total). The tank pushed the ends of the mats into the subgrade, but the mat ends would spring back to an upward curl after the tank moved off. The east edge of the mat was 3-1/4 in. above the subgrade as shown on Incl 15. A general view of item 1 after 2000 total passes is shown on Incl 16. Cross-section and profile curves (Incls 9-11) show little change

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4 October 1978

SUBJECT: Traffic Tests on M8A1 and M19 Landing Mats With and Without
Tl7 Membrane Underlay for Tactical Bridge Access/Egress
Applications

in the mat surface caused by 200 passes of the tank. The permanent set measurements (Incl 12) indicate an increase to 7 in. after 2000 total passes. After 3000 total passes, the mat was still in serviceable condition; however, several panels had breaks along the vehicle wheel paths. The maximum change in both cross-section (Incls 9 and 10) and profile (Incl 11) measurements from the beginning to 3000 total passes was 3.5 in. The item after 3000 total passes is shown on Incl 17.

7. When the panels were removed, 10 of the 24 panels contained breaks. A summary of panel damage is shown on Incl 18. Since the panels contained considerable permanent set, the mat would be most difficult to reconnect for reuse. The soil data (Incl 4) show that the subgrade strength was 1.6 CBR at the conclusion of traffic tests.

8. Item 2, traffic test (M8A1 mat with Tl7 membrane underlay). A general view of the item prior to traffic is shown on Incl 19. The initial truck passes produced noticeable deformation in the panels along the wheel paths. The deformation continued to increase and after 200 passes, the measurements (Incl 12) indicated a maximum change of 2-3/4 in. from a 18-ft string line stretched across the test section. The east edge of the mat was approximately 2 in. above the underlying subgrade. The maximum change in both cross-section (Incls 20 and 21) and profile (Incl 22) measurements from the beginning to 200 passes was 1.5 and 2.2 in. The mats continued to deform an average of approximately 0.5 in. between 200 and 1800 truck passes (Incls 20-22); however, no breaks or damage were noted after 1800 passes. The edges of the mat continued to curl upward with the maximum at the east edge of the mat which had increased to approximately 3 in. above the underlying subgrade. A view of the item after 1800 truck passes is shown on Incl 23.

9. The tank traffic caused the mat ends to curl upward during the next 200 passes. The east edge of the mat was 6-1/2 in. above the subgrade after 2000 total passes (Incl 24). Cross section and profile curves (Incls 20-22) show little change in the mat surface caused by the tank traffic. The permanent set measurements (Incl 12) indicate an increase to 5-1/2 in. after 2000 total passes. The item after 2000 total passes is shown on Incl 25.

10. After 3000 total passes, the mats were still in serviceable condition even though several panels contained breaks along the vehicle wheel paths. The maximum change in both cross-section (Incls 20 and 22) and profile (Incl 22) measurements from the beginning to 3000 total passes was 2.6 and 2.0 in. The item is shown at the conclusion of traffic in Incl 26.

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SUBJECT: Traffic Tests on M8A1 and M19 Landing Mats With and Without
T17 Membrane Underlay for Tactical Bridge Access/Egress
Applications

11. After the panels were removed, a visual inspection of panels revealed that 13 of the 24 panels in the item contained breaks. A summary of panel damage is shown on Incl 27. The panels contained considerable permanent set; therefore, the mat would be most difficult to reconnect for reuse. One punctured hole was noticed in the T17 membrane along the east wheel path. The soil data (Incl 4) show that the subgrade strength was 1.5 CBR at the conclusion of traffic.

12. Item 3, traffic test (M19 mat with T17 membrane underlay). The mat surface in item 3 was generally smooth at the beginning of traffic (Incl 28). As the rear truck wheels traversed the mat in a north and south direction along wheel paths which were centered 4 ft east and west of the center line, small hinging movements were occurring along the male-female connectors. These deflections are indicated on the 200 and 1800 passes curves as shown on Incls 29 and 30. A view of the item after 1800 passes is shown on Incl 31.

13. Tank traffic was applied for 200 passes (2000 total passes) and caused no significant change in the condition of the mat. After 3000 total passes, the mat was still in excellent condition. The maximum change in both cross-section (Incls 29 and 30) and profile (Incl 32) measurements from the beginning to 3000 total passes was 1.6 in. An overall view of the item at the conclusion of traffic is shown on Incl 33. The mud on the surface of the mat as shown on Incl 33 was caused by water leaking from holes in the hangar's roof onto subgrade which was tracked from items 1 and 4. After the panels were removed, no holes were noted in the T17 membrane. The soil data (Incl 4) show that the subgrade was 1.5 CBR at the conclusion of traffic.

14. Item 4, traffic test (M19 mat - no membrane underlay). Prior to traffic, the mat surface was generally smooth (Incl 34). Small hinging movements were occurring along the male-female connectors as the rear truck wheels traversed the mat in a north and south direction along wheel paths which were centered 4 ft east and west of the center line. Deflections along the wheel paths are indicated on the 200 and 1800 passes curves as shown on the 200 and 1800 passes curves as shown on Incls 35 and 36. The item after 1800 truck passes is shown on Incl 37.

15. The additional tank and truck traffic caused no significant change in the condition of the mat. The item after 3000 total passes is shown on Incl 38. The maximum change in both cross-section (Incls 35 and 36) and profile (Incl 32) measurements from the beginning to 3000 total passes was 1.2 and 1.5 in. The soil data show that the subgrade strength was 1.5 CBR at the conclusion of traffic.

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SUBJECT: Traffic Tests on M8A1 and M19 Landing Mats With and Without
T17 Membrane Underlay for Tactical Bridge Access/Egress
Applications

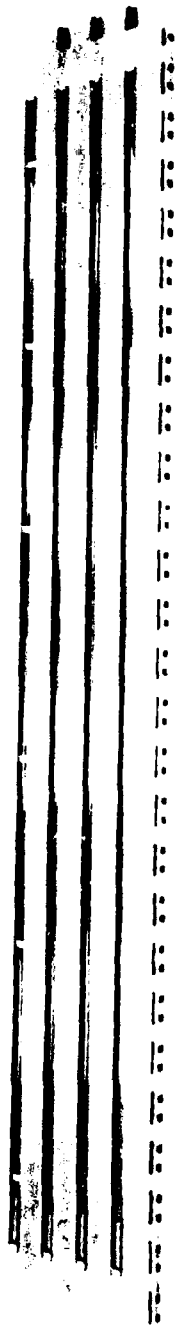
16. Traffic tests on unsurfaced and membrane surfaced items. After all the mat was removed from the test section, the T17 membrane on item 2 was moved to item 4 and the M51 dump truck was used to traffic the unsurfaced subgrade (items 1 and 2) and the membrane surfaced subgrade (items 3 and 4). The subgrade strength of the unsurfaced and membrane surfaced items was approximately 1.5 CBR. The test section prior to traffic is shown on Incl 39. The truck's first pass produced a 14-1/2-in. rut in the unsurfaced item (Incl 40) and a 6-1/4-in. rut in the membrane surfaced item (Incl 41). Each successive pass produced deeper ruts and after 10 passes, the rut depth on the unsurfaced and membrane surfaced items was 19 and 14-1/2 in. After 10 passes, the rear springs of the truck were dragging the subgrade for the entire length of the unsurfaced item (Incl 42) and the edges of the unanchored membrane were pulled into the ruts by truck traffic (Incl 43). The rear springs of the truck were also dragging along the membrane surfaced item. Truck traffic was discontinued after 10 passes.

17. Results of this investigation indicated that:

- a. All four of the test items sustained 3000 passes of the mixed truck and tank traffic and were serviceable for continued traffic.
- b. The T17 membrane underlays beneath items 2 and 3 prevented extrusion of soft subgrade material through the mat joints.
- c. The M8A1 panels in items 1 and 2 were not suitable for reuse because the panels were deformed and would be most difficult to reconnect.
- d. The M19 panels in items 3 and 4 were in good condition and were suitable for reuse.
- e. The M51 dump truck loaded with a gross weight of 40,000 lb can negotiate on a clay subgrade with a CBR of 1.5 for 10 repetitive passes.

43 Incl
as

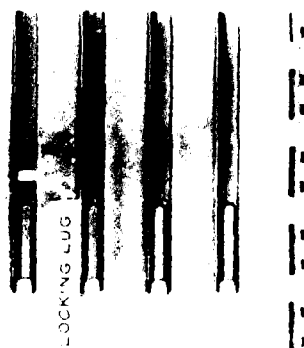
Carroll J. Smith
CARROLL J. SMITH
Engineer
Landing Mat Branch
Materiel Development Division



PLAN VIEW OF PANEL
NOMINAL DIMENSIONS
1-7 1/2 x 11-9 1/2



VIEW OF LEFT END



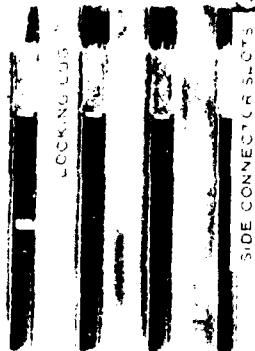
LOCKING LUG



BOTTOM VIEW RIGHT END



VIEW OF RIGHT END



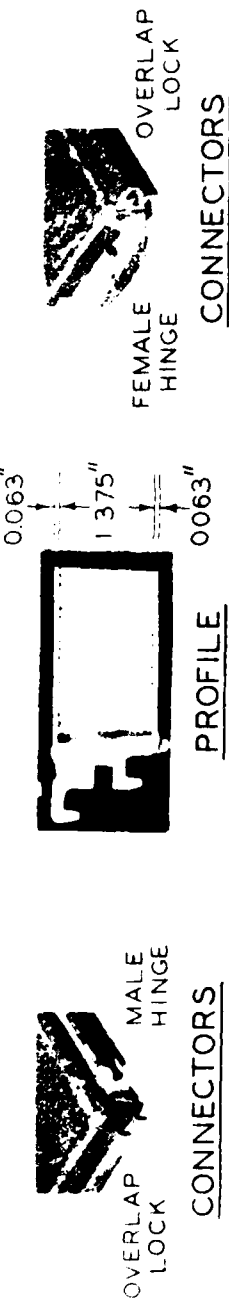
LOCKING LUG

SIDE CONNECTOR SLOTS (SLATS)



DETAIL OF RIGHT END

Composite view of M8A1 steel landing mat

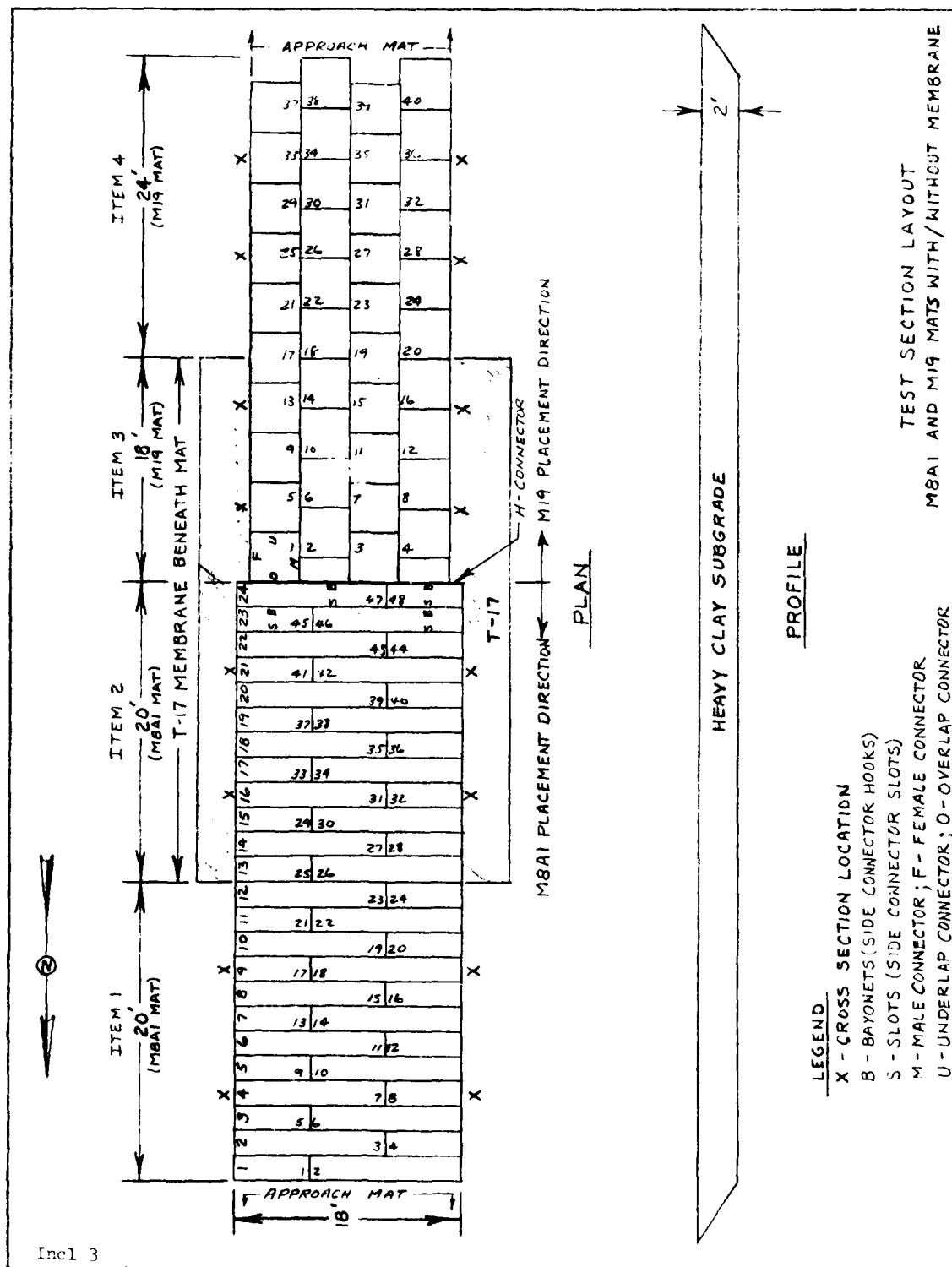


PLAN OF PANEL

NOMINAL DIMENSIONS
4'-2 1/4" x 4'-1 1/2"

AIRPLANE LANDING MAT, ALUMINUM,
SANDWICH TYPE, XM19

Composite view of M19 aluminum landing mat



Incl 3

SUMMARY OF WATER CONTENT, DRY DENSITY, AND CBR DATA

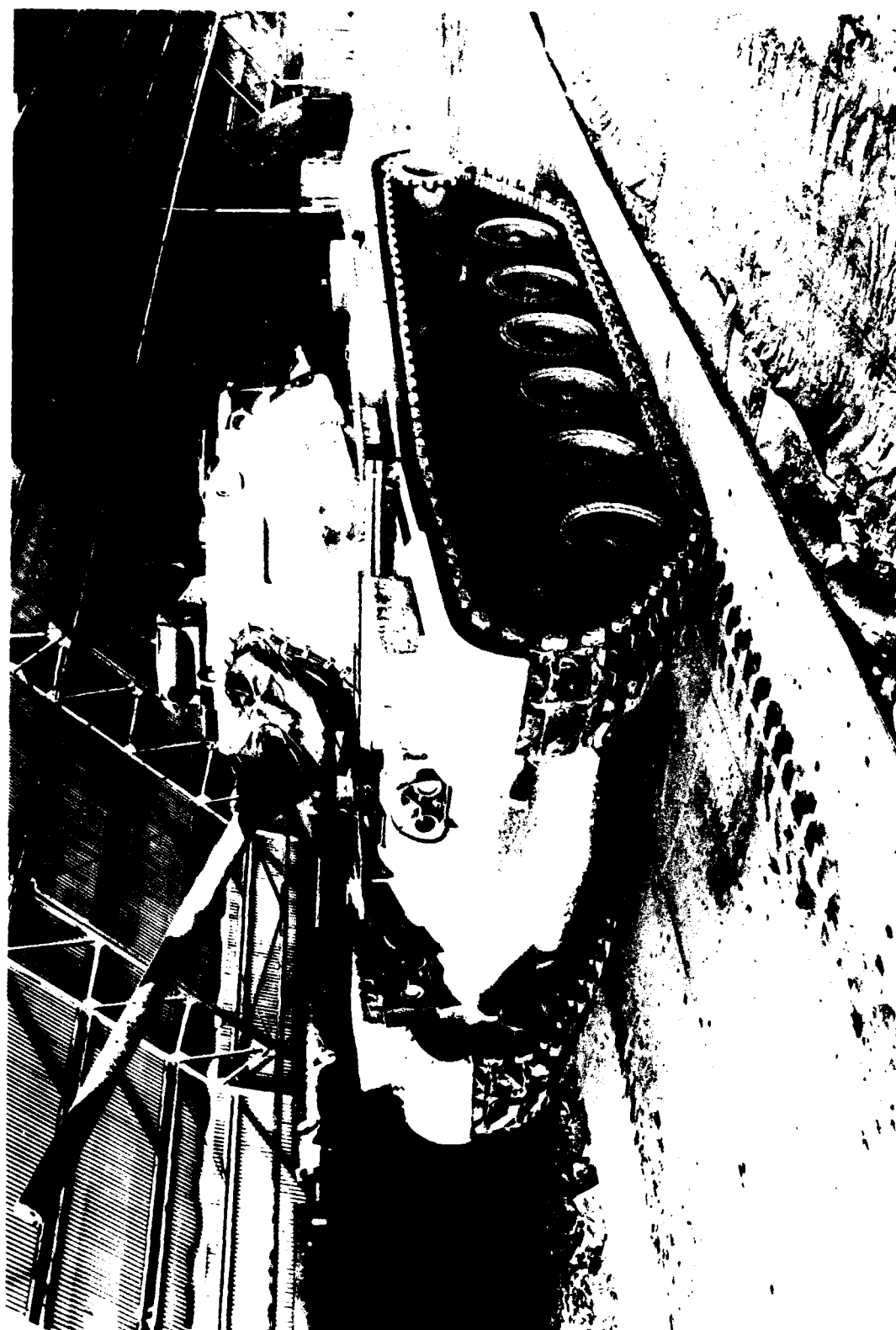
NUMBER OF PASSES	LOCATION	DEPTH IN.	WATER CONTENT %	DRY DENSITY PCF	CBR
0	RUN 24 (CENTERLINE OF SECTION)	0	34.1	81.5	1.0
		6	33.1	81.6	1.3
		12	33.0	81.9	1.3
		AVG	33.4	81.7	1.2
3000	RUN 6-ITEM 1 (4' EAST OF CENTERLINE)	0	33.4	83.1	1.6
		6	34.8	82.8	1.2
		12	32.3	84.0	2.1
		AVG	33.5	83.3	1.6
3000	RUN 18-ITEM 2 (4' WEST OF CENTERLINE)	0	34.0	83.2	1.4
		6	33.9	82.8	1.4
		12	33.4	84.5	1.8
		AVG	33.8	83.5	1.5
3000	PANEL 11-ITEM 3 (4' WEST OF CENTERLINE)	0	36.1	83.4	1.3
		6	35.0	83.7	1.4
		12	33.4	84.7	1.7
		AVG	34.8	83.9	1.5
3000	JOINT PANELS 22 & 26-ITEM 4 (4' EAST OF CENTERLINE)	0	35.0	83.0	1.4
		6	34.7	83.2	1.3
		12	33.9	84.2	1.8
		AVG	34.5	83.5	1.5

Incl 4





View of 5-ton, M51 dump truck loaded to 20,000 lb
(gross weight, 40,000 lb)

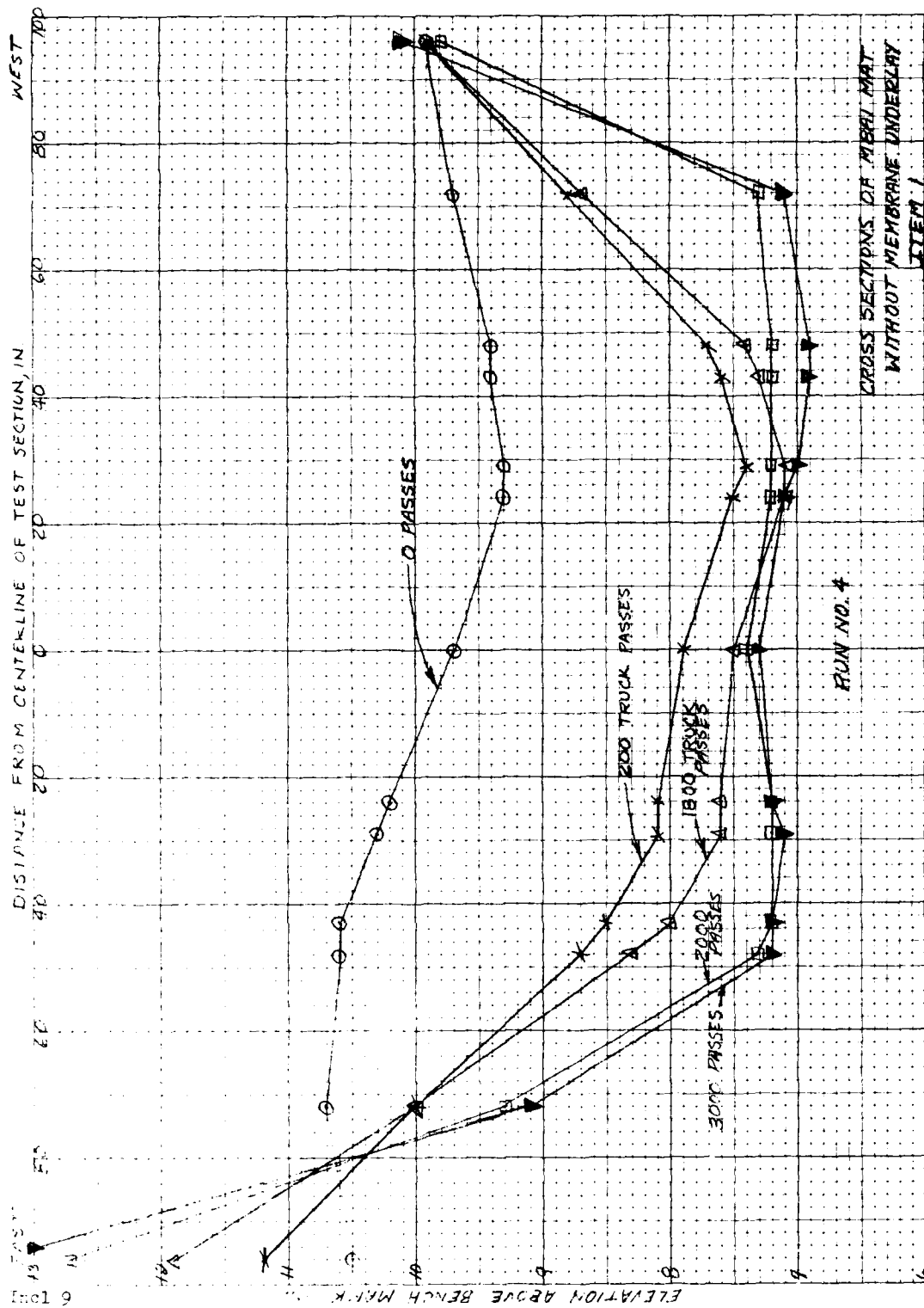


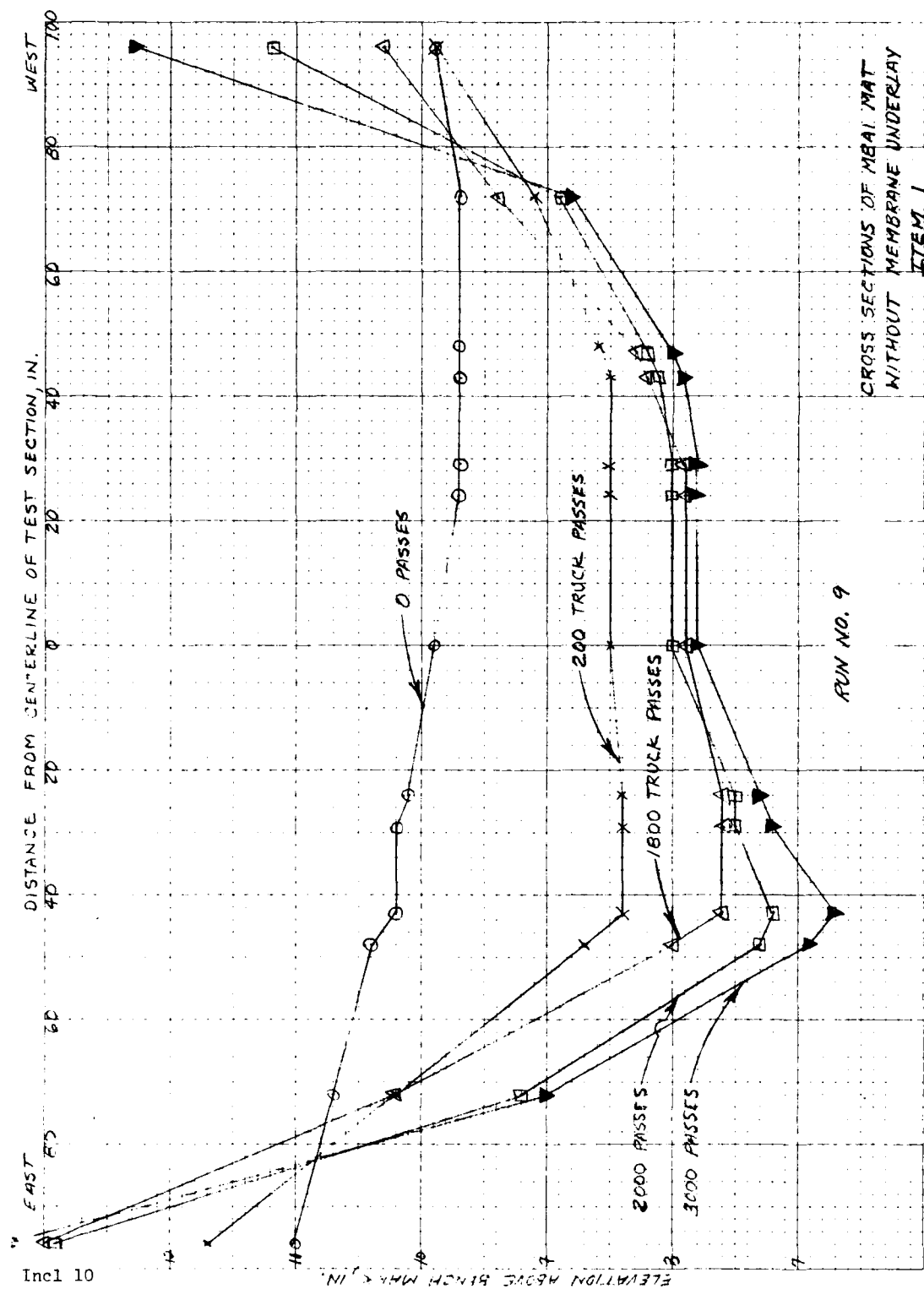
View of M48A1 combat tank loaded to 8000 lb
(gross weight, 106,000 lb)

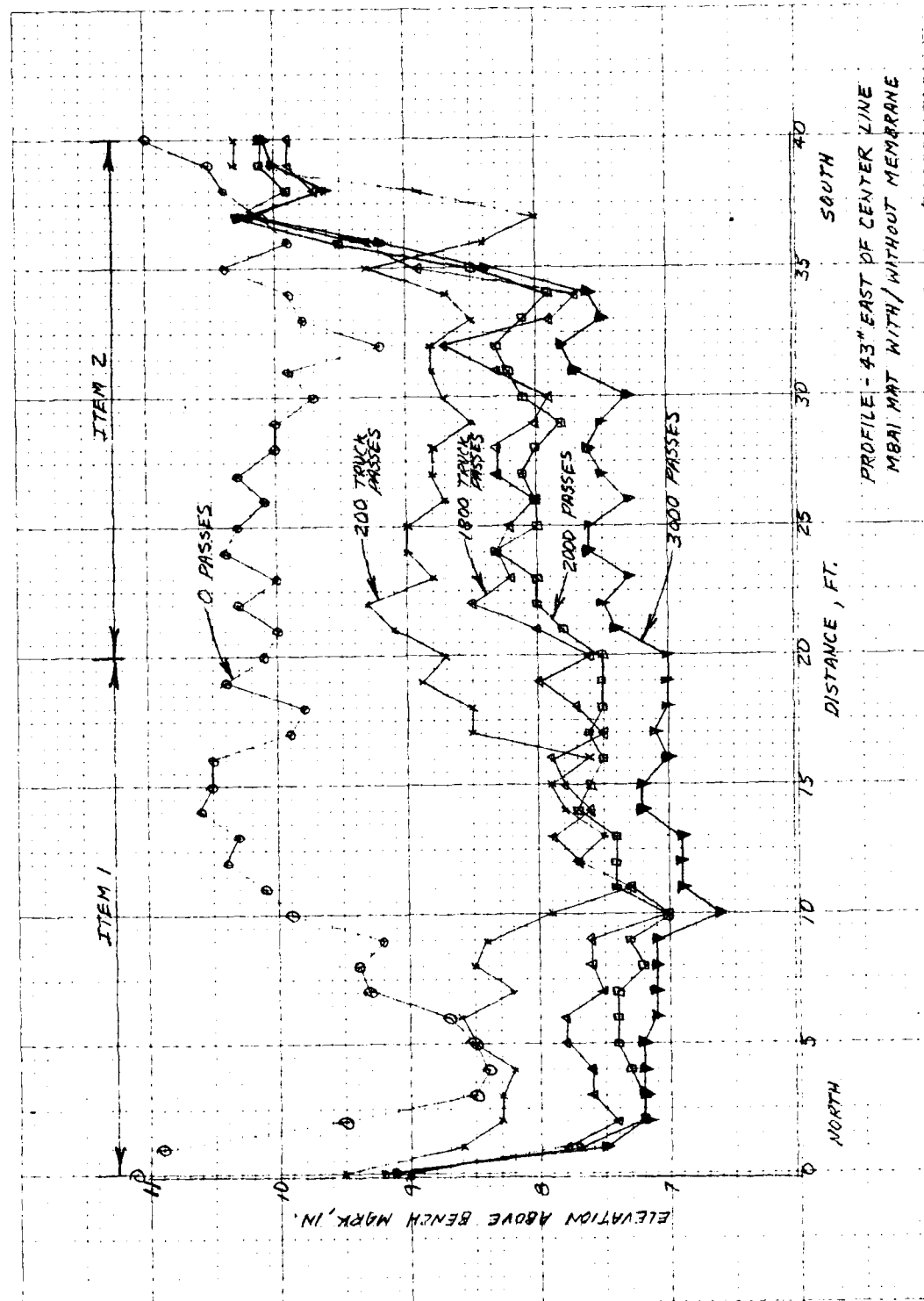
Incl 7



View of from 1 mile to 1 mile







Incl 11

PERMANENT SET OF MAT

DEVIATION FROM A 18-FT STRING LINE, IN.

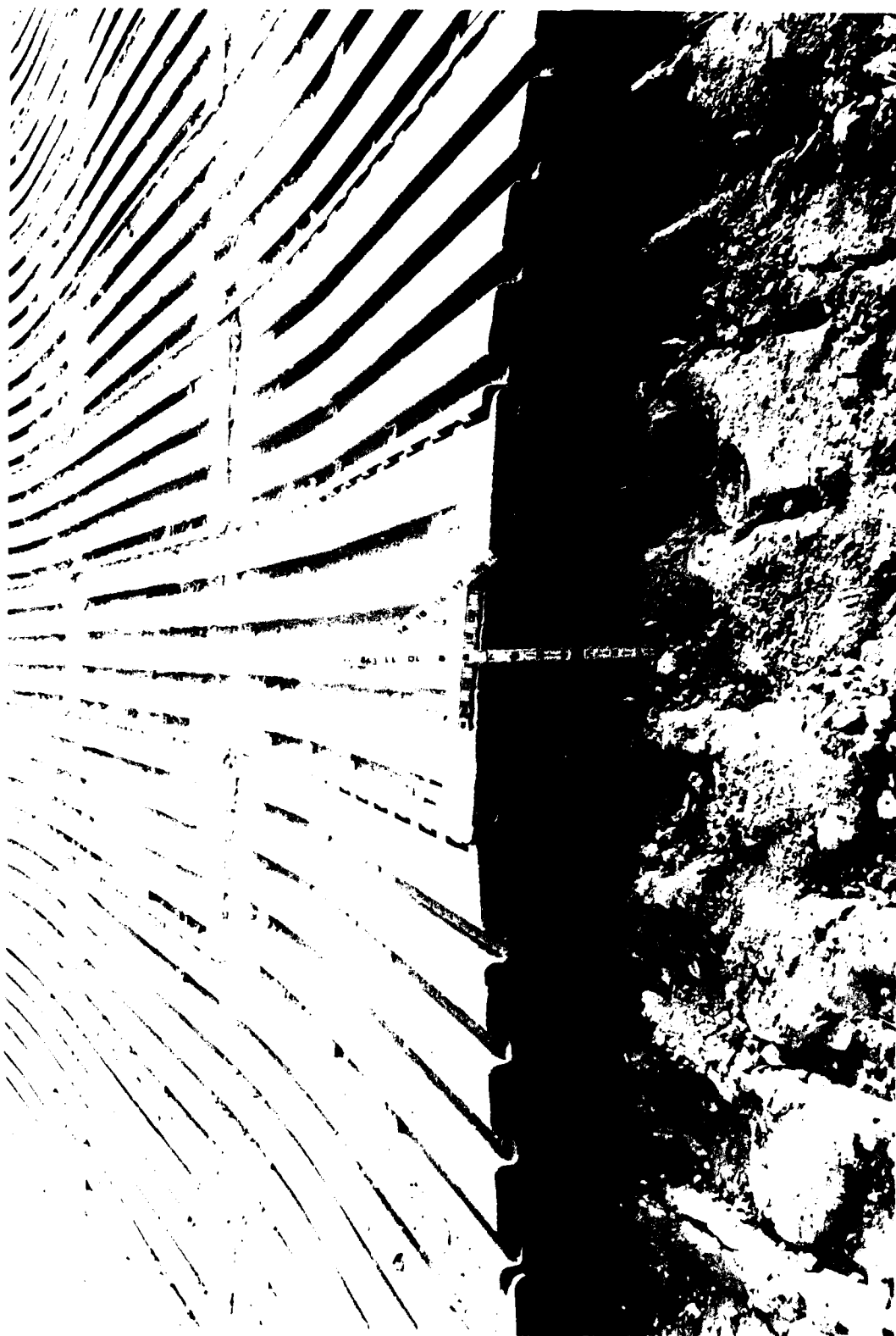
ITEM	RUN NO.	PASSES	EAST RUT	4	WEST RUT
1	4	200	2 5/8	3	3 1/4
	4	1800	4	4	4
	4	2000	6 1/2	6	6
1	7	200	3 1/4	3	2 3/4
	7	1800	4 1/2	3 3/4	3 1/4
	7	2000	7	6 1/8	6
1	9	200	3 1/8	2 1/2	2 1/4
	9	1800	5	4	3 1/2
	9	2000	7	6	5 1/2
2	15	200	1 1/4	3/4	3/4
	15	1800	2 1/2	2	1 7/8
	15	2000	4 1/4	3 1/2	2 1/2
2	18	200	1 1/2	1 1/4	1 1/4
	18	1800	2 1/2	2 1/4	2 1/2
	18	2000	5 1/8	4 1/4	4
2	21	200	2 3/4	2 1/4	2 1/4
	21	1800	3 1/2	3	3
	21	2000	5 1/2	5	5

Incl 12





Item 1 after 1800 truck passes



General Photo 0000 of a pipe from the 100 ft. well.





View of item 1 at the conclusion of traffic

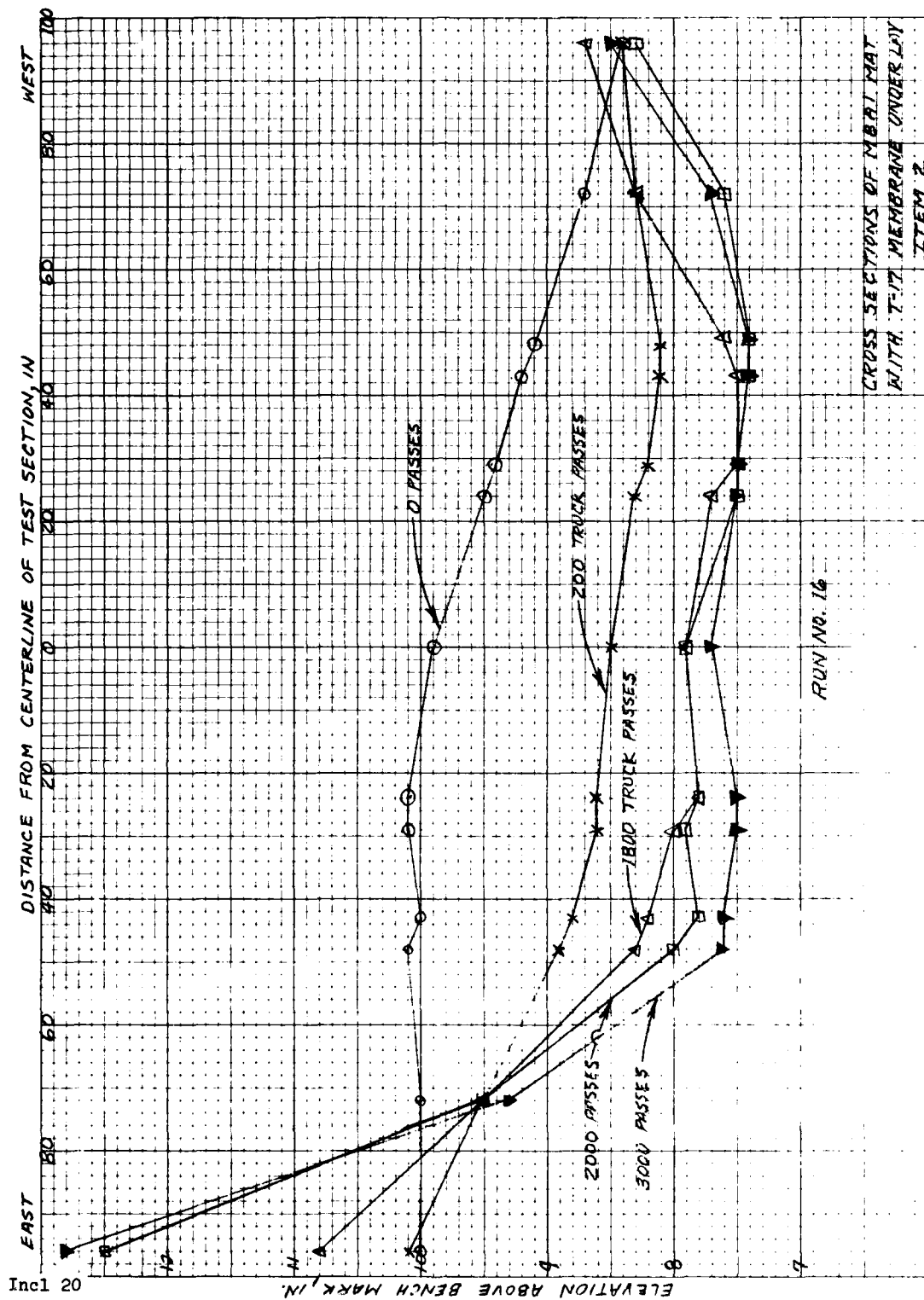
SUMMARY OF ITEM 1 PANEL DAMAGE AFTER 3000 PASSES

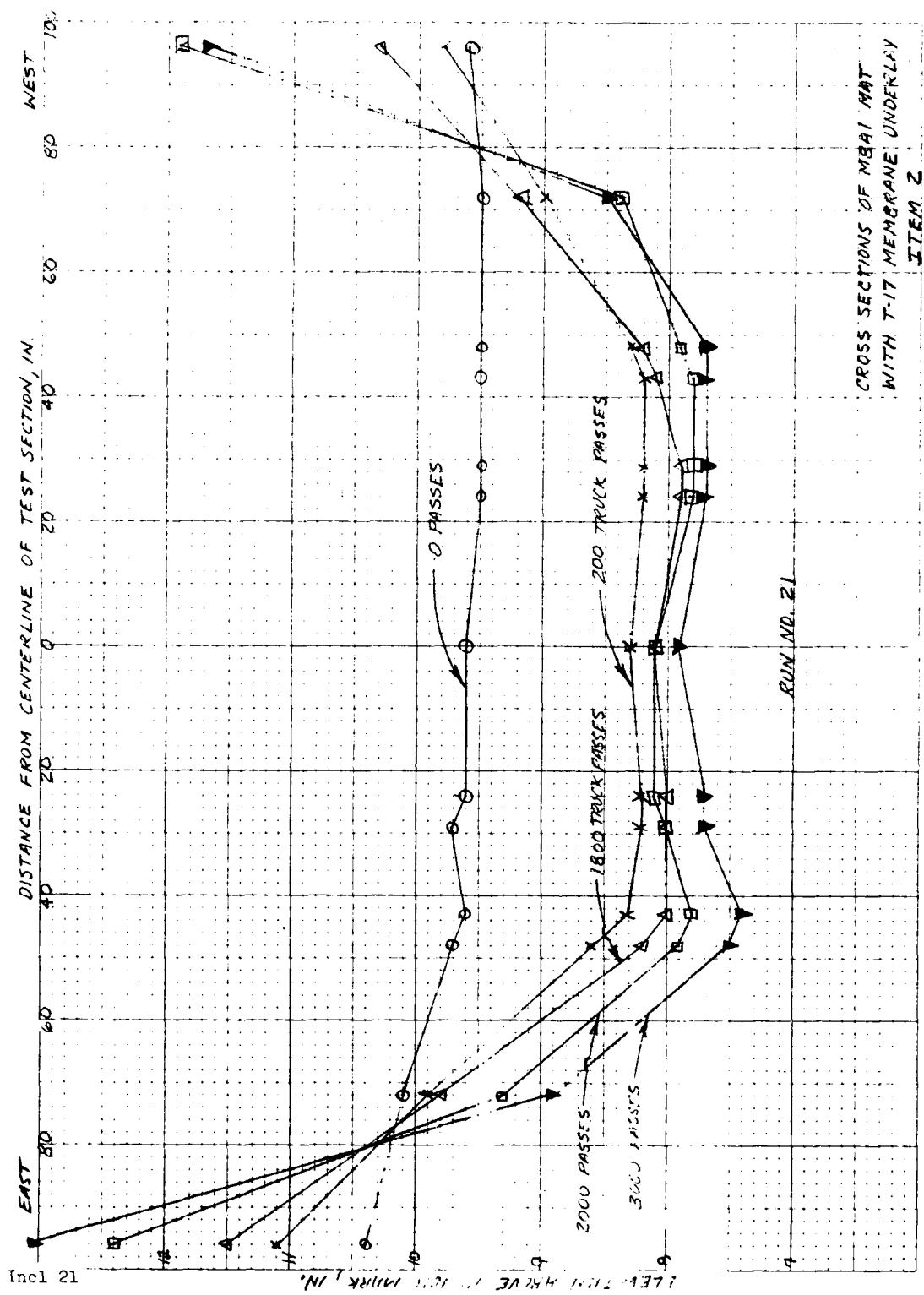
<u>PANEL NO.</u>	<u>DESCRIPTION OF DAMAGE</u>
3	Cover plate weld crack
5	Bayonet break
	Cover plate weld break
7	Cover plate weld crack
9	Cover plate weld break
13	Bayonet break
15	Cover plate weld crack
	Break from bayonet side extending through rib along east wheel path
17	Cover plate weld crack
	Bayonet broken off
	Break on the underlap connector extending from cover plate to end of panel
19	Cover plate weld crack
	Break from bayonet side extending through rib along east wheel path
	Break on the underlap connector extending from cover plate to end of panel
21	Bayonet broken off
23	Break from bayonet side extending through rib along east wheel path

Incl 18



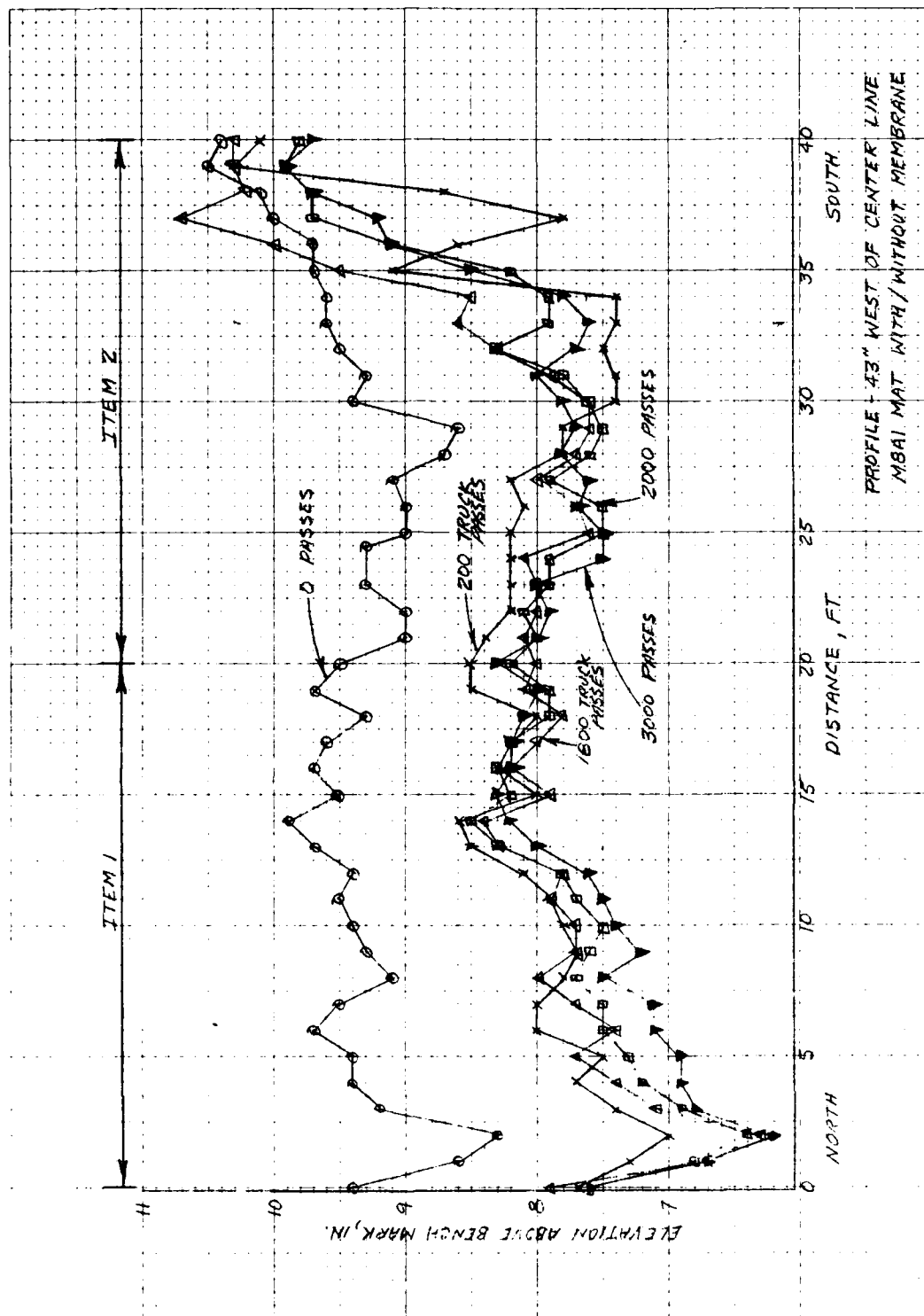
View of item 2 prior to transfer





Incl 21

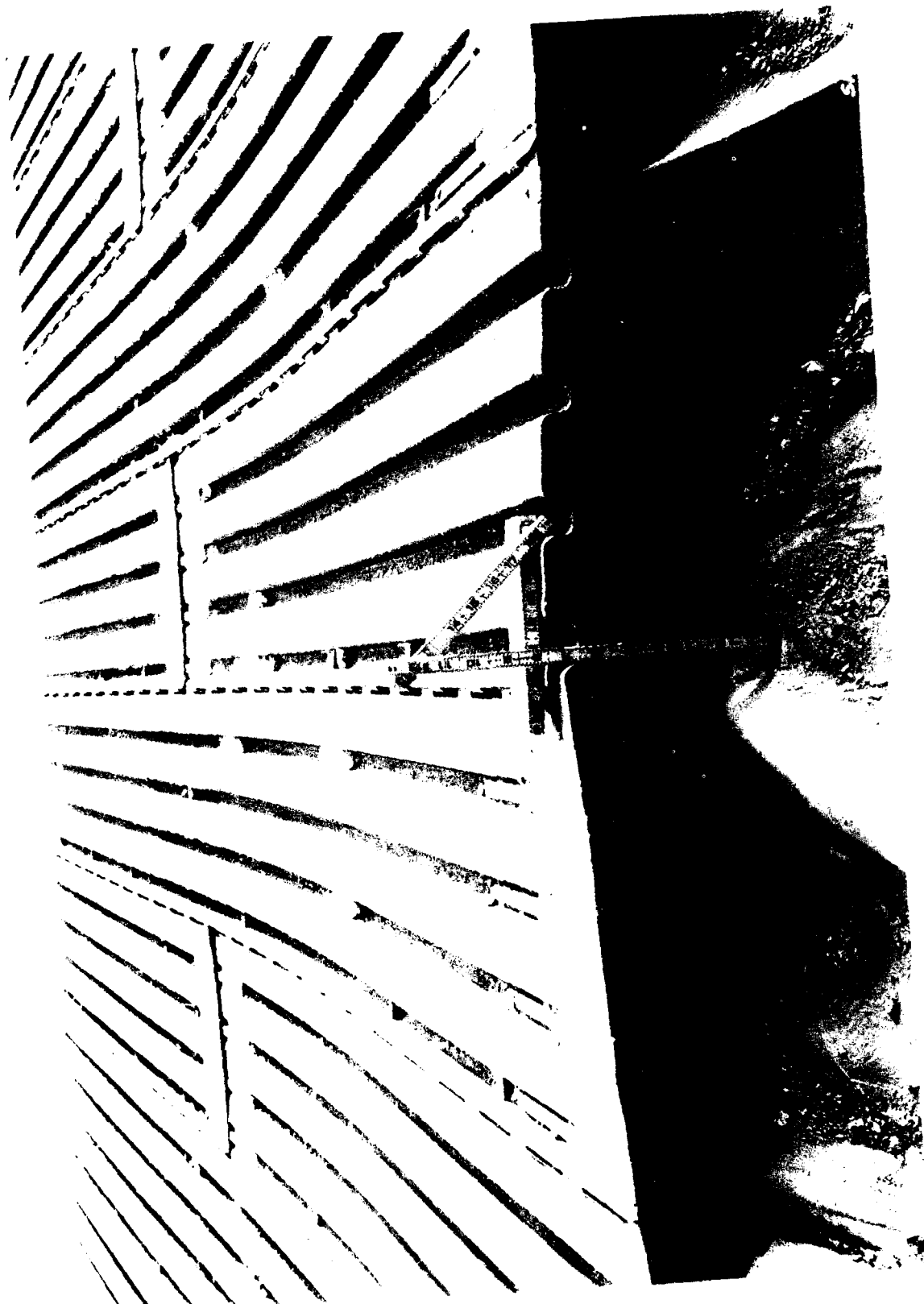
ELEVATION ABOVE 1987 MARK, IN.



Incl 22



Item 2 after 1800 truck passenger



Close up of the east mat edge after 2000 total passes



Item 2 after 2000 passes



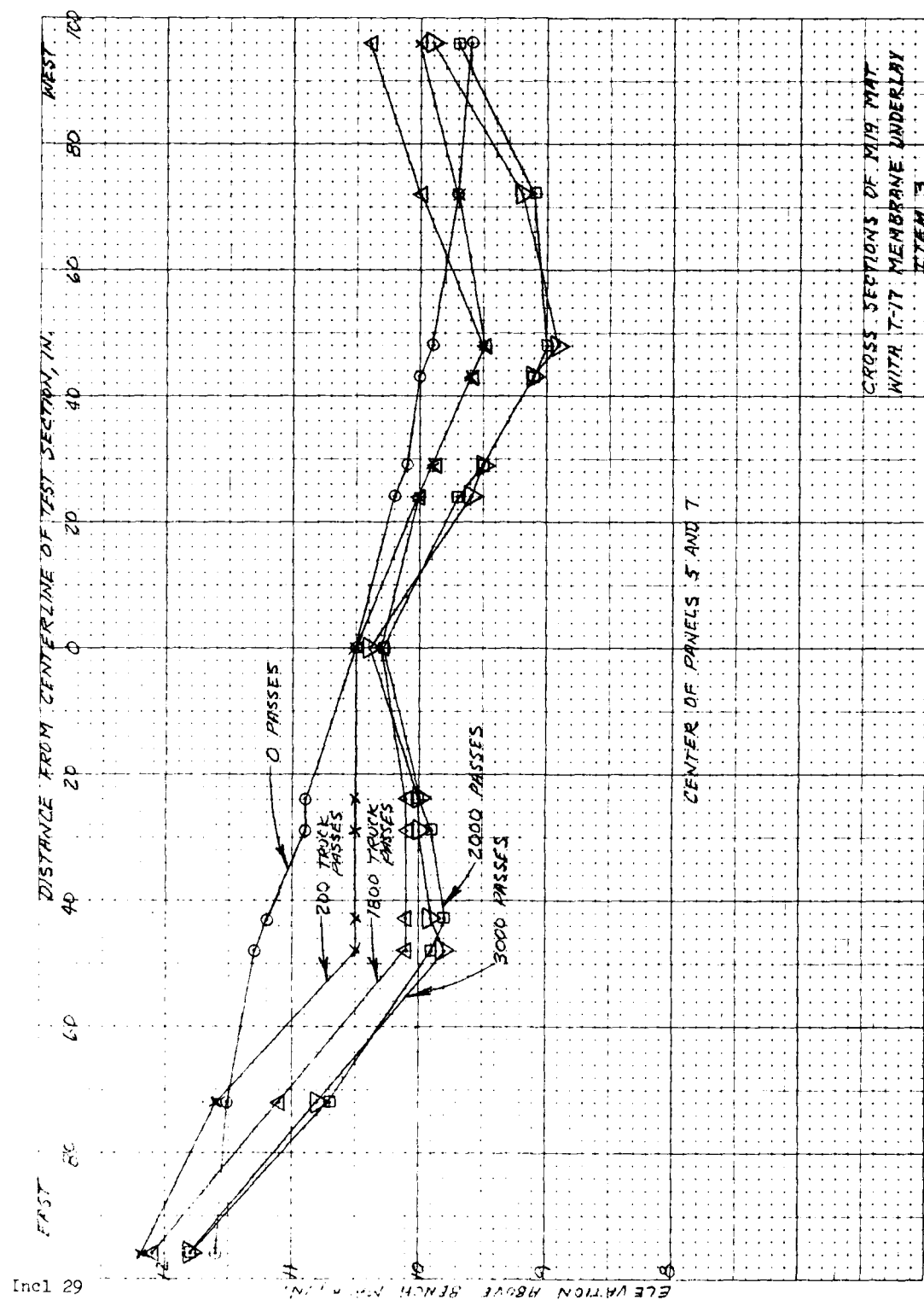
SUMMARY OF ITEM 2 PANEL DAMAGE AFTER 3000 PASSES

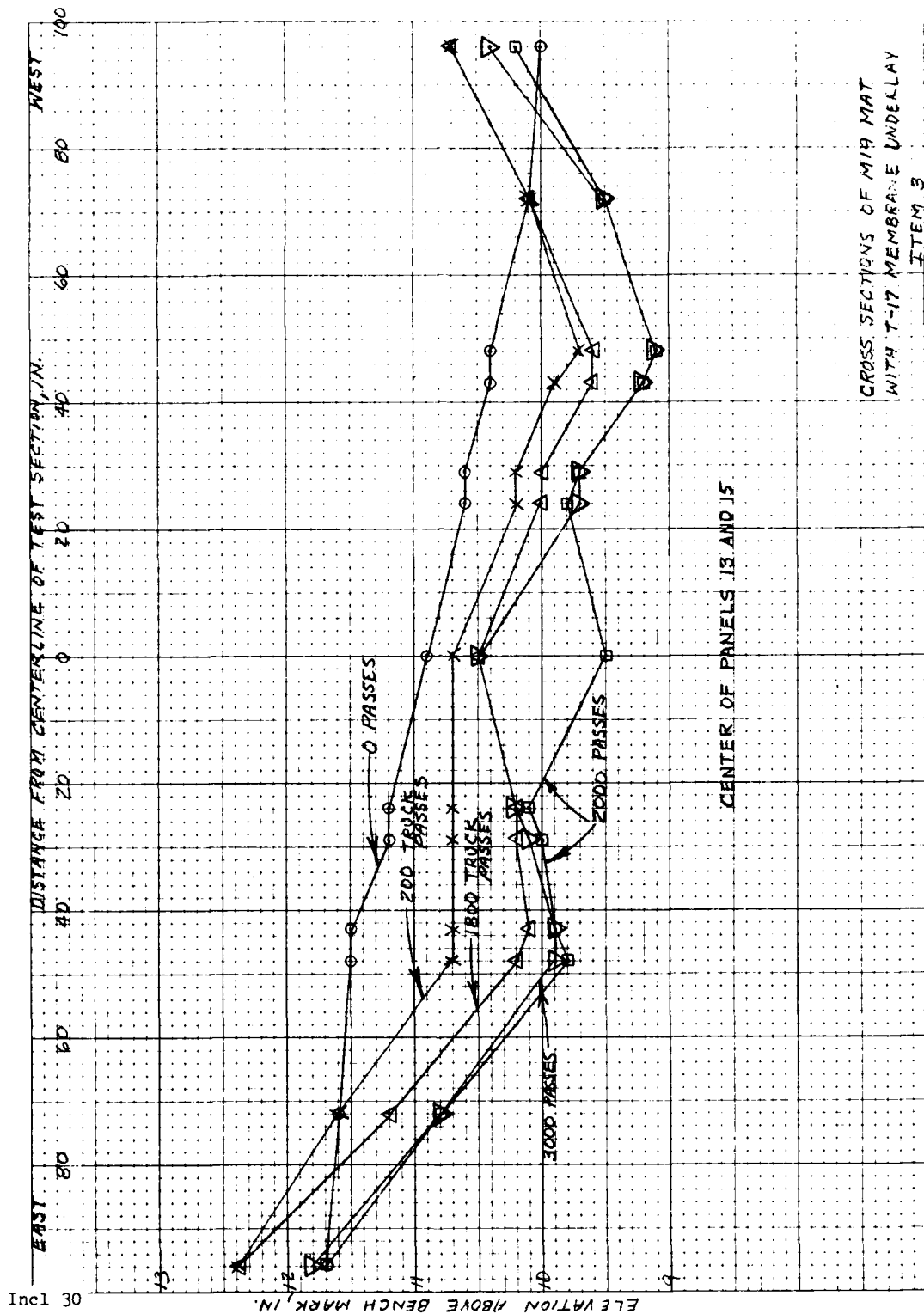
<u>PANEL NO.</u>	<u>DESCRIPTION OF DAMAGE</u>
25	Bayonet break
27	Cover plate weld crack Break on the underlap connector extending from cover plate to end of panel
29	Cover plate weld crack
30	Cover plate weld crack
31	Cover plate weld crack
33	Bayonet broken off
34	Cover plate weld break Break from bayonet side extending through rib along west wheel path
37	Bayonet broken off
38	Cover plate weld crack Break from bayonet side extending through rib along west wheel path
41	Bayonet broken off
42	Break from bayonet side extending through rio along west wheel path Cover plate weld crack
45	Bayonet break
46	Cover plate weld crack

Incl 27



View of How 3 pole to track



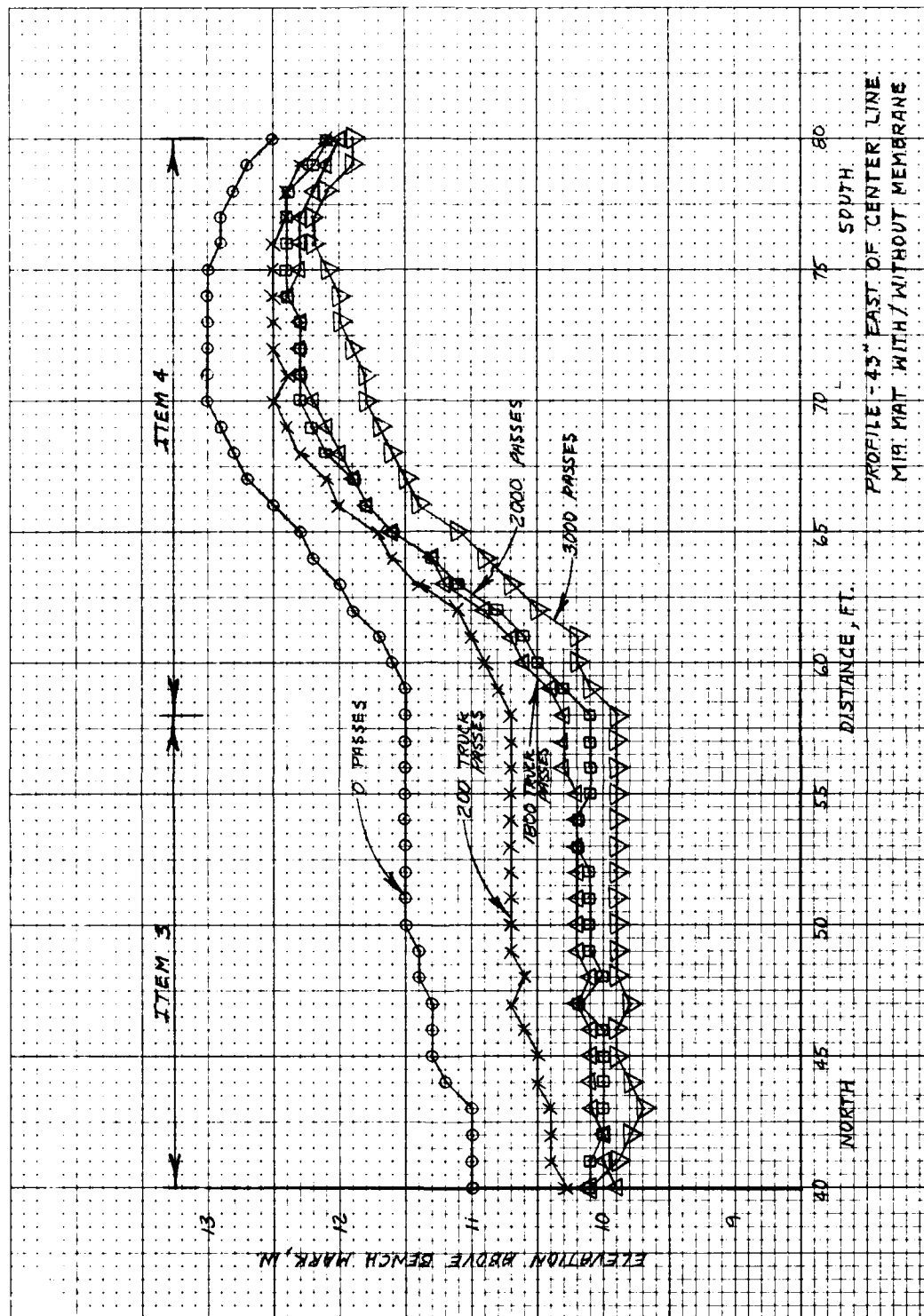


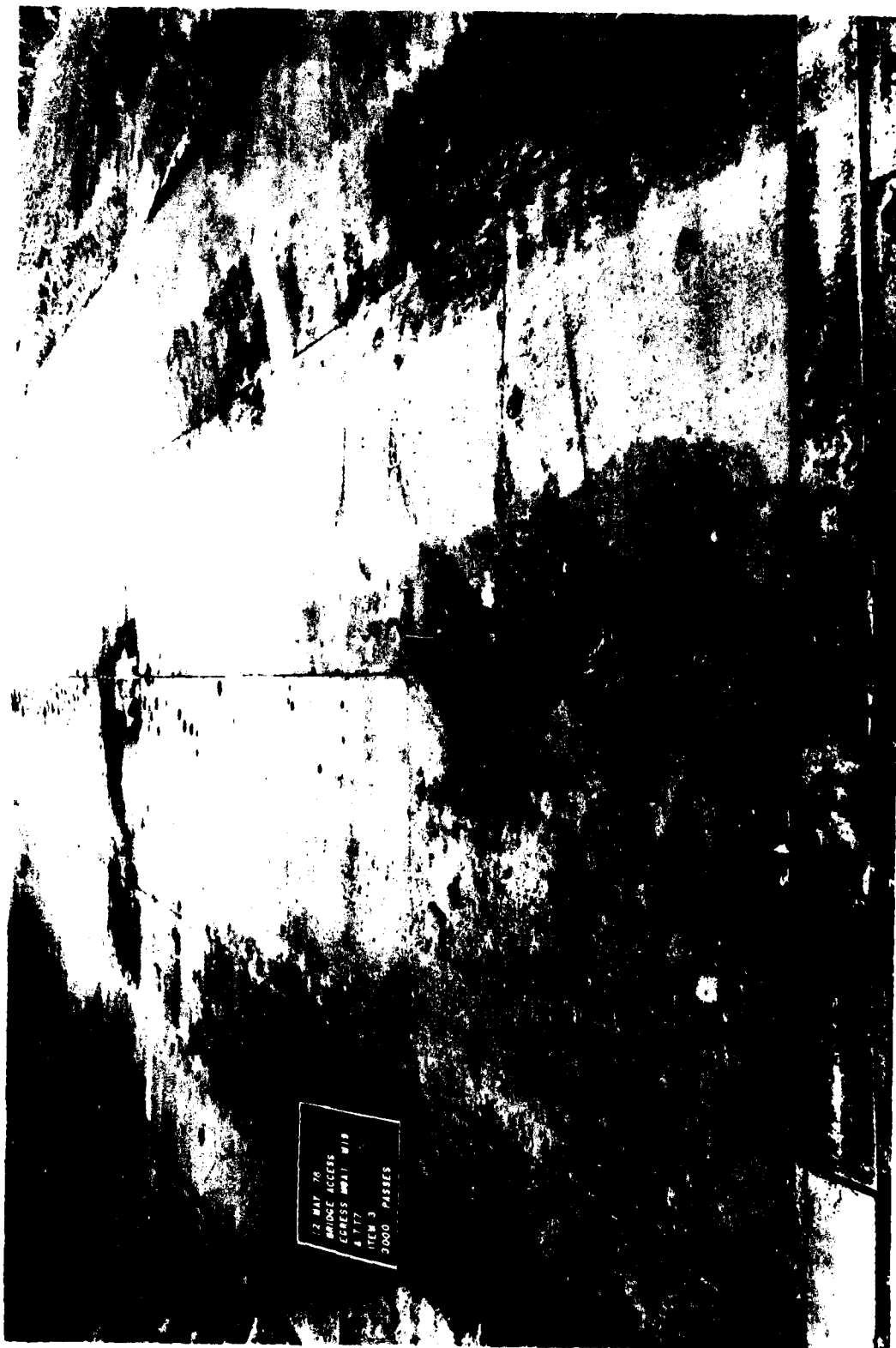


Item 3 after 1800 truck passes

Incl 31

Incl 32

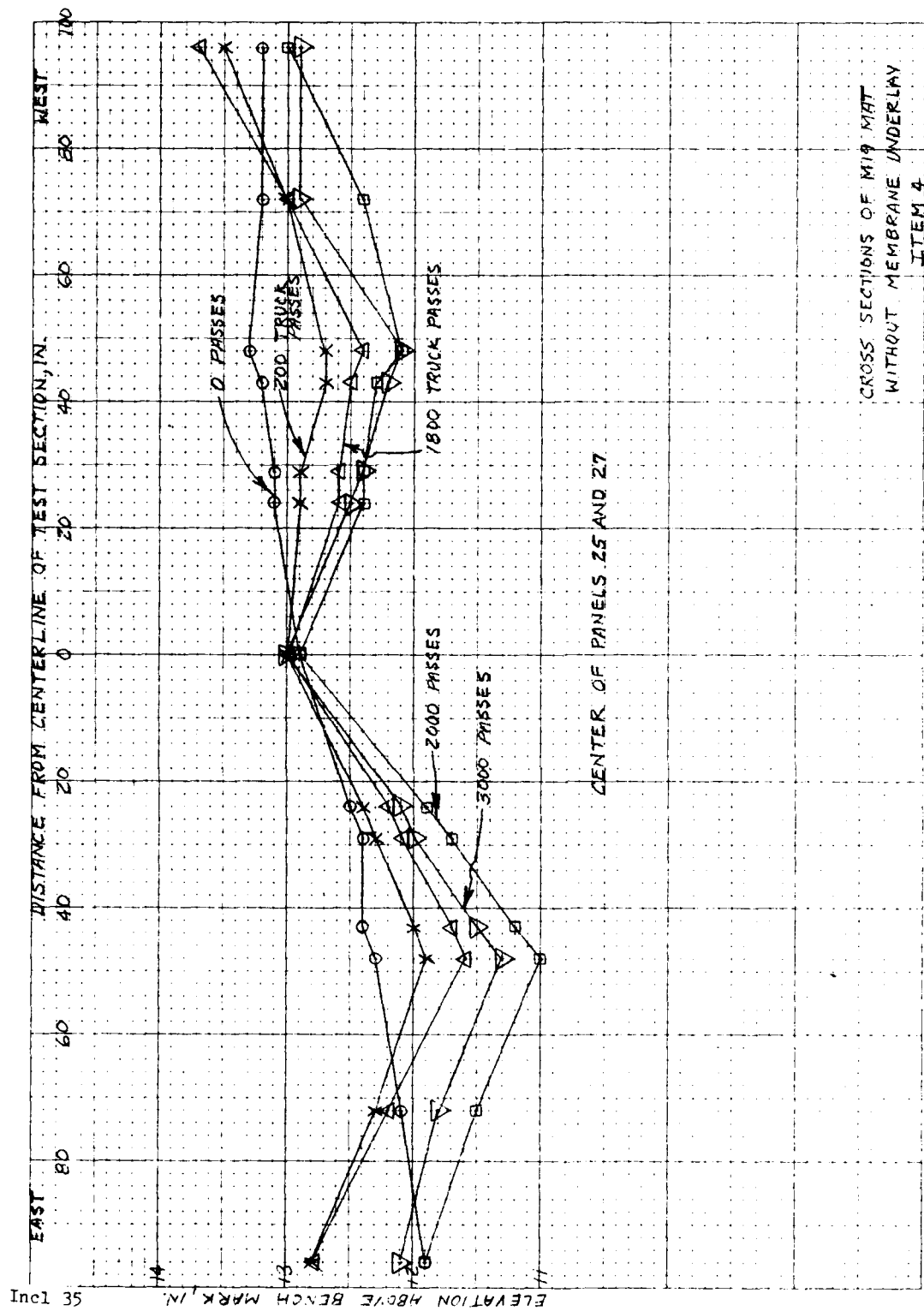


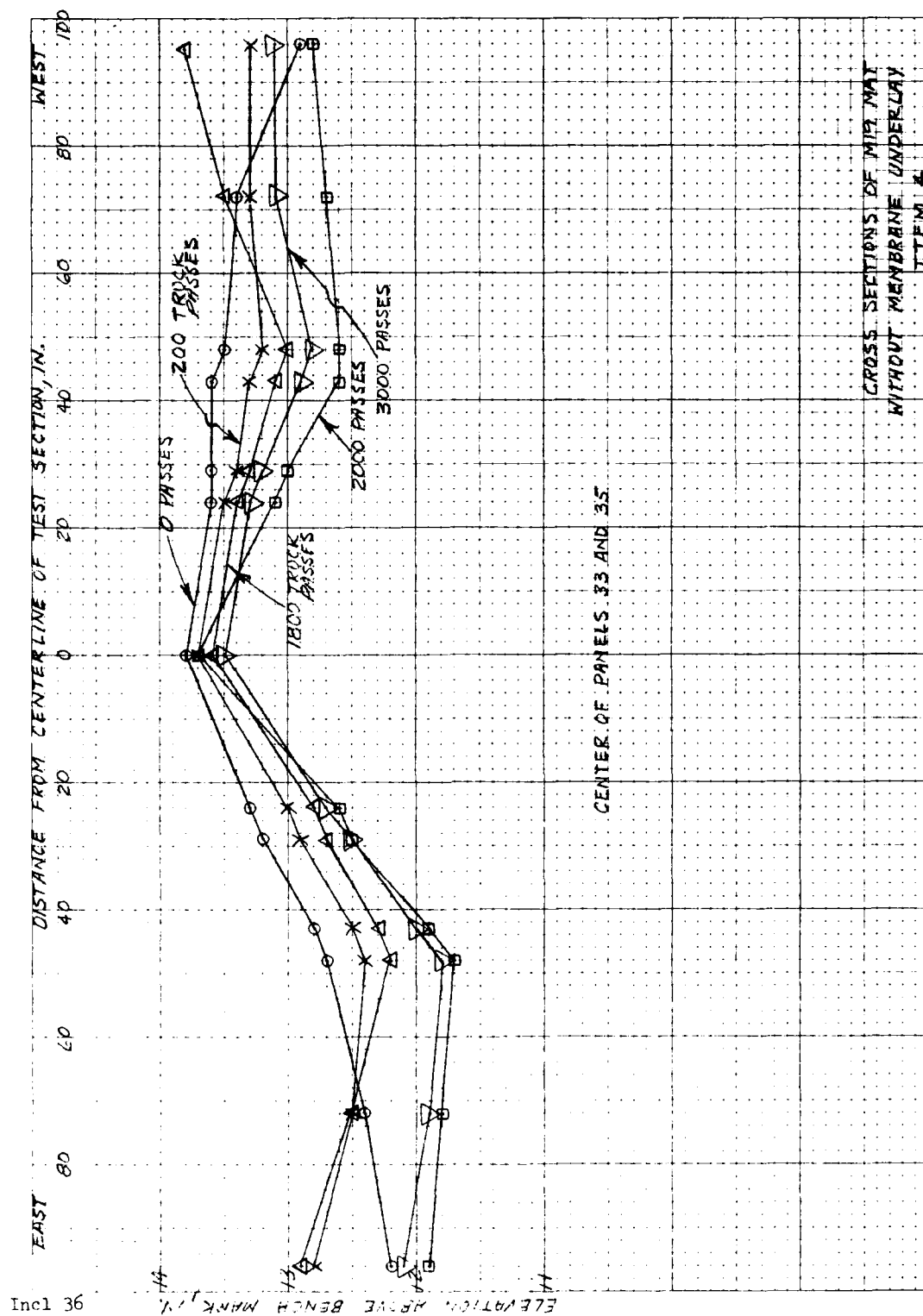


View of item 3 after 3000 total passes



View of item 4 prior to traffic





Incl 36

ELEVATION ABOVE BENCH MARK, IN.

9 MAY 79
MOBILE ACCESS
CARRIES MAIL 010
5.177
1700-4
1000 030003

1.0 MAY 70
BOMBING ACCIDENT
EXCESS MAIL 010
5.177
ITEM 4
2000 PAGES



Overall view of test section after the mat
was removed

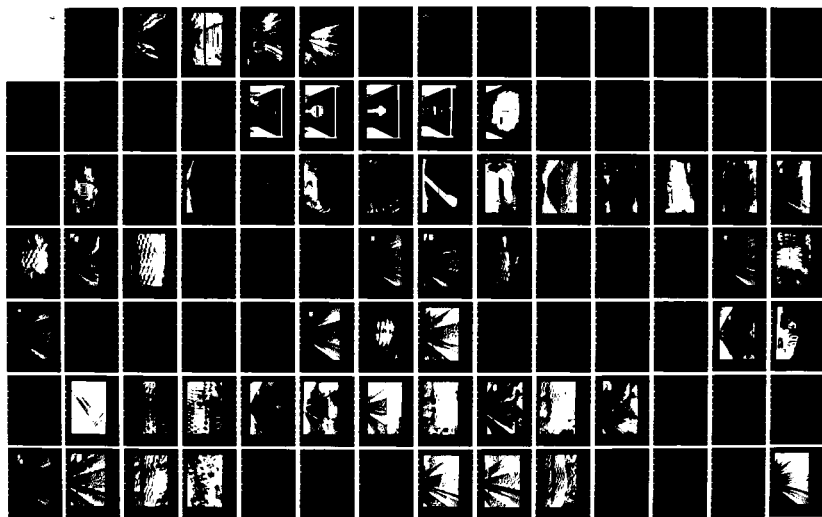
AD-A139 480

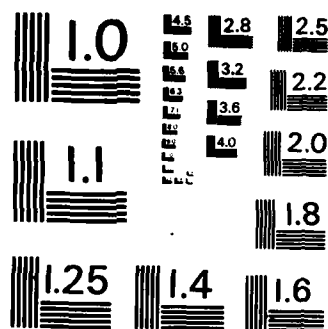
TACTICAL BRIDGE ACCESS//GRESS PRELIMINARY
INVESTIGATIONS(U) ARMY ENGINEER WATERWAYS EXPERIMENT
STATION VICKSBURG MS GEOTECHNICAL LAB B A MATIS SEP 80
F/G 13/2

3/6

UNCLASSIFIED

NL



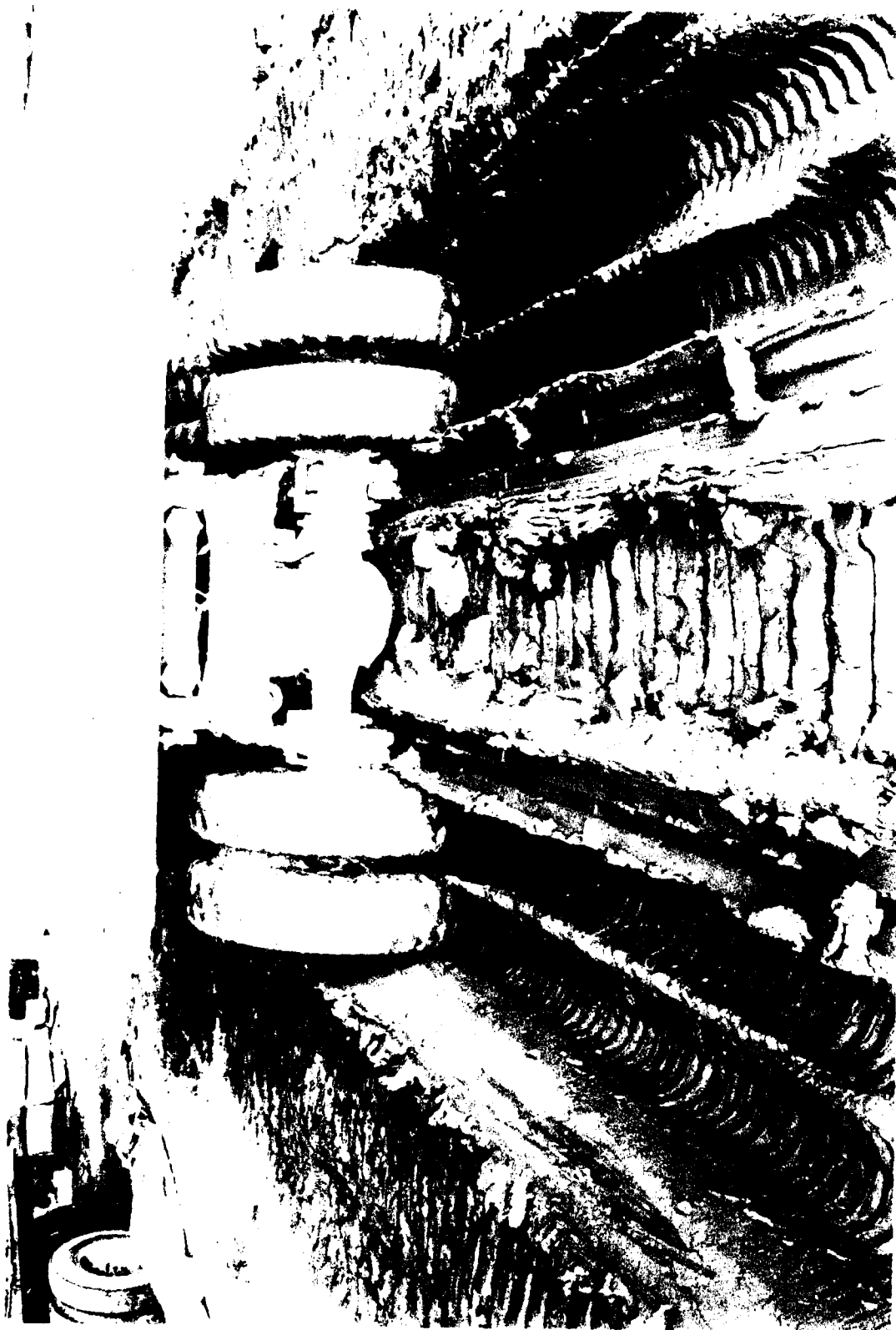


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A





View of the membrane surfaced item after
one pass of M51 dump truck



Truck on the unsurfaced item after 10 passes

MEMBRANE IN RUTS



Overall view of the roof section after 10 years.
Note: Membrane in rutting zone.

APPENDIX F

MEMORANDUM FOR RECORD--EVALUATION OF PAPER
AND ALUMINUM GRIDS FOR BRIDGE ACCESS/
EGRESS APPLICATIONS



DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESGS

25 June 1979

MEMORANDUM FOR RECORD

SUBJECT: Evaluation of Paper and Aluminum Grids for Bridge Access/Egress Applications

1. During the period of April-August 1978, both laboratory and traffic tests were conducted at the WES on various sizes of paper and aluminum grids. The investigations were conducted to determine the suitability of these materials as a potential soil strengthening system for bridge access/egress applications. It was envisioned that the resulting system would decrease the present time required in preparing access/egress in gap crossings. Therefore, during all evaluations there was no special subgrade preparations nor was there any compaction effort applied to the soil placed in the cells of the grids. Materials used in these tests are described as follows.

a. A paper honeycomb material fabricated from 90-lb linerboard, impregnated with 9-percent phenolic resin, formed by bonding 0.025-in.-thick sheets into a structure with 6-in. hexagonal cells that are 6 in. deep. The size of the honeycomb prior to expansion was 2-15/16 in. by 10 ft 8 in., and after expansion was 24 by 8 ft. This material had a total weight of 57 lb or 0.30 lb per sq ft expanded. (Note: The 9-percent resin content of this material was considered by the manufacturer to be the maximum amount that could be included and still allow the grid to be expanded once cured. Although an increase in the resin content would result in greater strength to the grid and render it more waterproof, it was not considered to be feasible in this type application.)

b. A honeycomb material fabricated from 0.014-in.-thick 3003-H14 aluminum alloy sheets, formed by bonding into a structure with 6-in. hexagonal cells that are 4 in. deep. The size of the honeycomb prior to expansion was 1-5/16 in. by 10 ft 1-1/2 in. and after expansion was 20 by 8 ft. This material had a total weight of 55 lb or 0.34 lb per sq ft expanded.

c. A honeycomb material fabricated from 0.014-in.-thick 3003-H14 aluminum alloy sheets formed by bonding into a structure with 6-in. hexagonal cells that are 6 in. deep. The size of the honeycomb prior to expansion was 1-3/8 in. by 10 ft 1 in. and after expansion was

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SUBJECT: Evaluation of Paper and Aluminum Grids for Bridge Access/Egress Applications

20 by 8 ft. This material had a total weight of 86 lb or 0.54 lb per sq ft expanded.

d. A honeycomb material fabricated from 0.014-in.-thick 3003-H14 aluminum alloy sheets formed by bonding into a structure with 6-in. hexagonal cells that are 8 in. deep. The size of the honeycomb prior to expansion was 1-1/2 in. by 10 ft 2-5/8 in. and after expansion was 20 by 8 ft. This material had a total weight of 127 lb or 0.79 lb per sq ft expanded.

e. A membrane fabricated from Kevlar material and covered on each side with a thin neoprene coating. This membrane was 0.013 in. thick with a weight of 1.8 oz per sq ft. It was supplied in 15- by 40-ft sections with a weight of 67 lb.

The grids and membrane described above are "off-the-shelf" type items that were procured from Hexcel Structural Products, Dublin, California, and Reeves Bros., Inc., Rutherfordton, North Carolina, respectively. Several square grids in various cell sizes and cell depths that were hand fabricated at the WES were also subjected to laboratory tests. This grid was being tested in other R&D work at WES and laboratory tests were conducted on it for comparison with the hexagon-shaped grids. These grids were fabricated from 0.028-in.-thick aluminum. To fabricate the square grids, strips of the aluminum material were initially cut for the proper cell depth. The strips were then cut at the proper spacings (depending on cell size) halfway through the depth of the strips to form slots. The individual strips were then nestled together at the slots to form the square cells of the grid.

Laboratory Tests

2. Samples of the various honeycomb and grid materials were tested in the laboratory with a model 1116 Instron testing machine with a 50,000-lb capacity. The test load was applied at a speed of 0.5 in. per minute and a stress-strain curve was recorded for each test specimen. The specimens were cut to fit within a test box which was 28 in. wide by 28 in. long, and 11-1/2 in. deep (Incl 1). The box size was based on the physical size of the test machine. The 6-in. cell size, 6-in. deep aluminum honeycomb grid is shown on this inclosure. Sand was placed in the box to a minimum depth of 2-3/4 in. prior to placing the honeycomb. Wood spacers initially were placed in the honeycomb to keep the cells properly expanded. The spacers were removed when the cells were almost filled with sand. Approximately 2 in. of sand was placed over the top of the grid prior to testing.

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3. The loading head was fabricated from a 3/4-in. steel plate placed on top of a 1/4 in. plywood plate sandwiched between rubber pads to simulate a single tire print (approximately 93 sq in.) of a M54 5-ton truck. A typical test set up prior to testing is shown on Incl 2. A test item at failure is shown on Incl 3. Sand has been partially removed from the aluminum grid in Incl 4 to show cell failure. The grids were subjected to these tests both with and without Kevlar membrane placed beneath the grids to determine what benefits, if any, the membrane would contribute. A typical membrane failure is shown on Incl 5.

4. Various sizes of paper and aluminum grid materials were subjected to the laboratory tests as described in paragraphs 2 and 3 above. Laboratory tests were also conducted on river and concrete sand without the benefit of any reinforcing material. Concrete sand was used for both the laboratory and traffic tests as it was more readily available, and it is similar to river sand (Incl 6). Load-deflection curves for the grid materials are shown on Incls 7 (hexagon cell without membrane), 8 (hexagon cell with membrane), and 9 (square cell without membrane). Various laboratory tests were also conducted on the Kevlar membrane alone. Results of these tests are given on Incl 10.

5. A summary of the laboratory tests conducted on the various grids with and without membrane underneath the grids is given on Incl 11. The deflection at 6000-lb load is shown for each grid. This load was used for comparison since this is the equivalent single-wheel load of the dual tandem wheel loading of the M54 5-ton cargo truck with gross weight of 40,000 lb. These test results show that the aluminum 6-in. hexagon cell, 4-in. depth, grid with membrane supported the 6000 lb with the least (0.90 in.) deflection. The aluminum 6-in. hexagon cell in the 6 and 8 in. depths with membrane was next in order of least deflection (1.00 in.). The rating based on load vs. deflection of these and the other grids tested is shown on Incl 11. All of the grids with or without membrane added considerable strength to the sand. The grid with membrane contributed as much as 95-percent increase (aluminum 6-in. hexagon cell size 4 in. depth with membrane) in the load (comparison of loads made at 2 in. of deflection) as compared to the same size grid without the membrane. The results of these tests with the membrane revealed that the distance the membrane is located from the surface has an effect on the overall strength of the grid/membrane system. The curves (Incl 8), prepared from laboratory test data for the aluminum grid, show that the closer the membrane is to the surface (to within 4 in.), the stronger the resulting system. Apparently, when the membrane was at depths of up to 8 in., the grid began to fail before the benefits of the membrane were fully utilized. The effect of the cell depth can be further seen from the data on Incl 11 since the aluminum 6-in. hexagon cell, 4 in. deep, supported the 6000-lb load with the least deflection and at a 2-in. deflection, supported more load than the other

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grid with or without membrane. The aluminum, 6-in. hexagon cell, 6-in.-deep grid without membrane supported the 6000-lb load with the least deflection of any of the grids without membrane and at 2-in. deflection, supported the most load. This grid also had less deflection at the 6000-lb load than the aluminum 6-in. hexagon cell 8 in. depth grid without membrane. The load (12,400 lb) at 2-in. deflection for the aluminum 6-in. hexagon cell, 6-in. deep grid without membrane was greater than for the aluminum 6-in. hexagon cell, 8-in.-deep grid with membrane (12,200 lb). The hexagon-shaped cell grids when compared to the same size and depth of square-shaped grids had about the same deflection at the 6000-lb load; however, at a 2-in. deflection, the hexagon-shaped grids supported more load (Incl 11). The results of these laboratory tests indicate that the aluminum 6-in. hexagon cell, 4- and 6-in.-deep cells with membrane, added the most strength to the sand.

Traffic TestsTest section 1

6. The test section was located under a hangar-type structure to provide protection from the elements. The subgrade of the test section consisted of a loosely placed sand (Incl 12) for a depth of 12 in. This sand was leveled with hand tools. The test section covered an area 88 ft long and 20 ft wide and consisted of items 1-4 as shown on Incl 13. Items 1 and 2 contained the 6-in. cell, 6-in. deep aluminum honeycomb grid without and with Kevlar membrane. Items 3 and 4 contained the 6-in. cell, 6-in. deep paper honeycomb grid with and without Kevlar membrane. An approach area was provided at each end of the test section to provide a maneuver area for the test vehicle during application of traffic. Inclosure 14 shows the completed test section subgrade with Kevlar membrane placed on items 2 and 3 prior to placement of the grid materials.

7. A slab of the 6-in. cell, 6-in. deep aluminum grid material prior to expansion is shown on Incl 15. The aluminum grid being expanded is shown on Incl 16. The grid was expanded in 40 sec using seven men. Sand was placed in the cells at each end of the grid section for anchorage to hold it in place. The grid was expanded and anchored in 1-1/2 min. Each slab of the grid when expanded formed a section 8 ft wide and 20 ft long. Items 1 and 2 were each 16 ft wide and 20 ft long; therefore, two slabs of grid were required for each item. A close-up of the expanded aluminum grid is shown on Incl 17.

8. A slab of the 6-in. cell, 6-in.-deep paper grid material prior to expansion is shown on Incl 18. A section of the paper grid being expanded

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is shown on Incl 19. The paper grid was expanded and anchored in approximately the same time as the aluminum grid. No difficulties were experienced in expanding the grid nor was there any separation at the glue lines.

9. A completed section of grids prior to filling with sand is shown on Incl 20. Sand was placed in the grids with a front end loader from the edges of the test section. The sand did not cause any damage to the individual cells as it was dumped onto the grids. For these preliminary evaluations, hand tools were used to level the sand in the grids. No compactive effort was applied, and it was placed so that it covered the top edges of the grids by 2 in. A view of the overall test section prior to traffic is shown on Incl 21.

10. The preliminary evaluation of the various grids and combinations with membrane were trafficked with an M54, 5-ton cargo truck (Incl 22) which had a gross weight of 20,000 lb on 11X20, 12-ply tires inflated to 35 psi. Traffic was applied in a channelized pattern similar to that which would be encountered in actual road conditions.

11. Elevation measurements (cross section and profile) of the test section surface were recorded before, during, and after traffic to determine permanent deformation of the test section and to reveal the amount of roughness. The profile readings were taken along the wheel paths of the test vehicle. Visual observations of the test section materials were recorded throughout the period of traffic and supplemented by photographs.

12. A view of the test section after 10 passes of the M54 truck is shown on Incl 23. Some rutting and compaction of the sand and grids had occurred. No visible evidence of deformation of the grids was observed. However, when the sand was removed from the top of some of the grids in one wheel path, some deformation and tears were observed. Details of the individual items are given in the following paragraphs.

13. Item 1, 6-in. cell, 6-in. depth aluminum grid. The surface of item 1 was rutted as much as 4.1 in. after 10 passes of traffic (Incl 24). Sand was removed from the top of some of the grid in one wheel path. The walls of the grid at the top were slightly bent (Incl 25). As traffic was continued, the depth of the ruts increased; however, the sand covered the cells of the honeycomb and there was no other evidence that the cells were deteriorating. Traffic was continued until 1000 passes were completed (Incl 26). The item was still in good condition and the truck did not have any difficulty in trafficking the item. The rut depth had increased to 7.7 in., the top edges of the grid in the wheel paths had bent over, and there was some separation and tearing of the grid at the glue line (Incl 27). The cells adjacent to the wheel paths were not deformed or torn at the glue line between the individual cells. The cross section (Incl 28) and profile (Incl 29) data show that the greatest change in elevation occurred

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in the first ten passes with only minor changes between 10 to 200 and 200 to 1000 passes.

14. Item 2, 6-in. cell, 6-in. depth aluminum grid on membrane. The surface of this item was rutted as much as 3.8 in. after 10 passes of traffic (Incl 30). Sand was removed from the top of some of the grid in one wheel path. The walls of the grid at the top were bent similar to that in item 1. The rut depth increased as traffic was applied. The cells remained covered with sand, and there was no visible evidence that the cells were deteriorating. Traffic was continued until 1000 passes were completed (Incl 31). The item was still in good condition, and the truck did not have any difficulty trafficking the item. The rut depth had increased to 7.2 in. However this is less than the rut depth (7.7 in.) of the grid tested without the membrane (item 1). The top edges of the grid in the wheel paths were bent and there was some separation and tearing of the grids at the glue line between individual cells (Incl 32). The edges of the cells in this item were bent over more at the top than those in item 1 without membrane underneath the grids, which indicated that this grid system was apparently carrying more load. The cells adjacent to the wheel paths were not deformed or torn at the glue line. The cross section (Incl 33) and profile data (Incl 34) show that the greatest change in elevation occurred in the first ten passes with only slight changes between 10 to 200 and 200 to 1000 passes.

15. Item 3, 6-in. cell, 6-in. depth, paper grid on membrane. The surface of this item was rutted as much as 6.8 in. after ten passes of traffic (Incl 35). Sand was removed from the top of some of the grid in one wheel path. The walls of the grid near the top were bent and torn (Incl 36). Although the paper was impregnated with phenolic resin, it had absorbed moisture from the sand and the walls of the cells had lost their stiffness. The rut depth increased as traffic was applied and after 200 passes, the depth was 10.8 in. (Incl 37). The grid after 200 passes had lost its effectiveness as the paper had absorbed moisture from the sand and the cells had disintegrated. The membrane appeared to hold the moisture in the grids in this item more so than in item 4 where there was no membrane. The rut depth was also greater in this item than it was in item 4. This item was considered failed at this time due to the ineffectiveness of the paper grid. The cross section (Incl 38) and profile data (Incl 39) show that the most change in elevation occurred in the first ten passes; however, there was additional change between 10 to 200 passes.

16. Item 4, 6-in. cell, 6-in. depth paper grid. The surface of this item was rutted as much as 7.4 in. after 10 passes of traffic (Incl 40). Sand was removed from the top of some of the grid in the wheel path. The walls of the grid near the top were bent and torn (Incl 41). The paper had absorbed moisture from the sand and the walls of the cells had lost

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their effectiveness as the paper had absorbed moisture from the sand and the cells had disintegrated. Thus, the item was considered failed at 200 passes. The cross section (Incl 43) and profile data (Incl 44) show that most of the change in elevation occurred in the first ten passes; however, there was additional change between 10 to 200 passes.

17. An overall view of the test section after 1000 passes of traffic is shown on Incl 45. (Note: In paragraphs 15 and 16, items 3 and 4 were failed after 200 passes; however, the truck was not stopped on the test section but trafficked from one approach to the other approach.) The M54 truck on items 1 and 2 is shown on Incl 46.

Test section 2

18. This test section was constructed in the same location and prepared in the same manner as that mentioned for test section 1 in paragraph 6. The depth of the sand was the same, however, this section covered an area 80 ft long and 20 ft wide and consisted of items 5-8 as shown on Incl 47. Items 5 and 6 contained the 6-in. cell, 4-in. depth aluminum honeycomb grid both without and with Kevlar membrane, respectively. Items 7 and 8 contained the 6-in. cell, 8 in. depth, aluminum honeycomb grid with and without Kevlar membrane. An approach was provided at each end of the test section to provide a maneuver area for the test vehicle during application of traffic. The M54 truck used to traffic test section 1 was also used for these tests.

19. Unexpanded slabs of the 6-in. cell, 8-in. depth, and 6-in. cell, 4-in. depth, are shown on Incl 48. These grids were expanded, anchored, and filled with sand as described for the 6-in. cell, 6-in. depth grid in paragraphs 7 and 9. These grids required about the same amount of installation time as did the 6-in. depth grid. A close up of the 4-in. and 8-in. depth cells after expansion is shown on Incls 49 and 50, respectively. The cells were filled with sand and a 2-in. layer of sand was placed over the top edges of the grids. The test section prior to traffic is shown on Incl 51.

20. Elevation measurements (cross section and profile) of the test section surface were recorded before, during, and after traffic to determine permanent deformation of the test section and to reveal the amount of roughness. The profile readings were taken along the wheels path of the test item. Visual observation of the test section and materials were recorded throughout the period of traffic and supplemented by photographs.

21. The test section after ten passes is shown on Incl 52. Some rutting and compaction of the sand and grids had occurred. Several areas where the grids had moved under traffic in item 5 are noted on the photograph.

SUBJECT: Evaluation of Paper and Aluminum Grids for Bridge Access/Egress Applications

There was no other visible evidence of movement or deformation of the grids. However, when the sand was removed from the top of some of the grids in one wheel path, some deformation and torn areas were observed. Details of the individual items are given in the following paragraphs.

22. Item 5, 6-in. cell, 4-in. depth aluminum grid. The surface of this item was rutted as much as 5.8 in. after ten passes of traffic (Incl 53). Sand was removed from the top of some of the grid in one wheel path. The walls of the grid at the top were slightly bent (Incl 54). As traffic was continued, the depth of the ruts increased and the movement of the grid at the center of the item had also increased at 500 passes (Incl 55). There was no other visible evidence that the grids were deteriorating; however, when the sand was removed from the cells, more bending had occurred along with tearing of the cell walls beneath the wheel path (Incl 56). Traffic was continued until 1000 passes were completed. The rut depth at this time was 6.7 in.; some of the grid had worked out of the sand between the wheel paths, and the grids had failed in the wheel paths. The cells were no longer confining the sand (Incl 57). The cross section (Incl 58) and profile (Incl 59) data show that the majority of the change in elevation occurred in the first ten passes with slight changes between 10 to 200 and 200 to 1000 passes.

23. Item 6, 6-in. cell, 4-in. depth, aluminum grid on membrane. The surface of this item was rutted as much as 4.4 in. after ten passes of traffic (Incl 60). Sand was removed from the top of some of the grid in one wheel path. The walls of the grid at the top were slightly bent similar to the grid in item 5. As traffic was continued, the depth of the ruts increased and at 500 passes was 7.3 in. The grid in this item had failed after 500 passes (Incl 61) as it was no longer effective in confining the sand. Pieces of the grid are circled on this photograph. Sand was removed from the top of some of the grid in one wheel path. The cells were almost completely crushed and some of the cell walls were separated from the grid section (Incl 62). The surface of the membrane in the wheel path beneath the 4-in. grid is shown on Incl 63. The action of the grid on the membrane abraded the neoprene coating; however, no holes were cut or torn in the fabric of the membrane. The cross section (Incl 64) and profile (Incl 65) data show that the majority of the changes in elevations occurred in the first ten passes with additional changes between 10 to 200 and 200 to 500 passes.

24. Item 7, 6-in. cell, 8-in. depth aluminum grid on membrane. The surface of this item was rutted as much as 3.6 in. after ten passes of traffic (Incl 66). Sand was removed from the top of some of the grid in one wheel path for inspection. The tops of the walls of the cells were slightly bent similar to the grid in item 5. As traffic was continued, the depth of the ruts increased. Traffic was continued until 1000 passes

SUBJECT: Evaluation of Paper and Aluminum Grids for Bridge Access/Egress Applications

were completed (Incl 67). The item was still in good condition, and the truck did not have any difficulty trafficking the item. The rut depth had increased to 4.6 in. The top edges of the grid in the wheel paths had bent over, and there was some separation and torn grids at the glue line between the cell walls (Incl 68). The cells adjacent to the wheel paths were not deformed nor torn at the glue line between individual cells. The cross section (Incl 69) and profile (Incl 70) data show that the greatest change in elevation occurred during the first ten passes with additional changes between 10 to 200 and 200 to 1000 passes.

25. Item 8, 6-in. cell, 8-in. depth, aluminum grid. The surface of this item was rutted as much as 3.6 in. after ten passes of traffic (Incl 71). Sand was removed from the top of some of the grid in one wheel path. The tops of the walls of the cells were slightly bent similar to the grid in item 5. As traffic was continued, the depth of the ruts increased. Traffic was continued until 1000 passes were completed (Incl 72). The item was still in good condition, and the truck did not have any difficulty trafficking the item. The rut depth had increased to 4.9 in. The top edges of the walls of the cells in the wheel paths were bent over, and there were some torn grids at the glue line between the cell walls (Incl 73). This condition was more pronounced than in item 7 where the membrane was placed beneath the grids. The cells adjacent to the wheel paths were not deformed nor torn at the glue line between individual cells. The cross section (Incl 74) and profile (Incl 75) data show that the greatest change in elevation occurred during the first ten passes with additional changes between 10 to 200 passes and 200 to 1000 passes.

26. An overall view of the test section with items 5-8 after 1000 passes of traffic is shown on Incl 76.

Test section 3

27. In order to obtain a direct comparison between a loosely placed sand subgrade without any reinforcing materials on top of the surface and test sections with reinforcing materials, a section of loosely placed sand, 20 in. deep, was prepared (Incl 77). Fiber-glass panels of open grating design, which are shown on the test section, were also subjected to the truck traffic. Traffic was applied with the M54 truck with 20,000-lb gross weight. The section after two passes is shown on Incl 78. The rut depth on the unsurfaced portion was 7 to 8 in. After two passes, the fiber glass panels were rotated 90 deg to the way they are shown on Incl 77. After 50 passes, the rut depth on the unsurfaced sand (Incl 79) varied from 11 to 12 in., and the rear housing of the truck was touching the sand subgrade. The section was reworked and leveled (Incl 80). The gross weight and tire pressure of the truck were increased to 40,000 lb and 70 psi, respectively, and traffic was resumed. The loaded M54 truck

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became immobilized in the loose sand in an attempt to make one pass through the test section (Incl 81). The truck went only about 20 ft in the loose sand prior to being immobilized, and the rut depth was greater than 12 in. Inclosure 82 shows the test section after the truck was removed. Several areas where the undercarriage of the truck had touched the subgrade can be seen on this photograph. A summary of the results of tests on unsurfaced and surfaced sand subgrade is given on Incl 83.

28. Results of this investigation are:

a. The load that grid samples will withstand in laboratory tests is increased by placing a membrane beneath the grids. The aluminum, 6-in. hexagon cell grid in the 4 and 6 in. depths with membrane added more strength to sand than did the other sizes and depths of grids either with or without membrane.

b. The 6-in. hexagon cell, 6-in. depth paper honeycomb grid tested both with and without membrane absorbed moisture from the sand and failed after 200 passes of traffic with the M54 cargo truck (20,000 lb gross weight) with tires inflated to 35 psi. The rut depth with and without membrane was 10.8 and 9 in. The grid was no longer effective in confining the sand.

c. The 6-in. hexagon cell, 4-in. depth aluminum honeycomb grid tested with membrane was failed after 500 passes of traffic with the M54 cargo truck (20,000 lb gross weight) with tires inflated to 35 psi. The rut depth was 7.3 in. The grid was no longer effective in confining the sand. This same size grid without membrane was failed after 1000 passes of traffic with the M54 truck and was no longer effective in confining the sand. The rut depth was 6.7 in. Since the grid without the membrane sustained more traffic than the grid with the membrane, the membrane was considered detrimental to the 4-in. depth grid.

d. The 6-in. hexagon cell, 6-in. depth aluminum honeycomb grid tested with and without membrane was serviceable and confined the sand after 1000 passes of traffic with the M54 cargo truck (20,000 lb gross weight) with tires inflated to 35 psi. The rut depth with and without membrane was 7.2 and 7.7 in.

e. The 6-in. hexagon cell, 8-in. depth, aluminum honeycomb grid tested with and without membrane was serviceable and confined the sand after 1000 passes of traffic with the M54 cargo truck (20,000 lb gross weight) with tires inflated to 35 psi. The rut depth with and without membrane was 4.6 and 4.9 in.

25 June 1979

SUBJECT: Evaluation of Paper and Aluminum Grids for Bridge Access/Egress Applications

28. Conclusions and recommendations are as follows:

a. The strength of the grids when tested in the laboratory were increased by using a membrane beneath the grids.

b. The laboratory test give an indication of what materials or combination of materials are the strongest when tested with a loading head that simulates the tire print of a single wheel of the M54, 5-ton cargo truck. However, to fully evaluate a material or combination of materials for use on the bridge access/egress application, tests with the moving vehicle must be conducted.

c. The paper grid, impregnated with 9 percent phenolic resin, with and without membrane, and the aluminum 6-in. hexagon cell, 4 in. deep, with and without membrane provided some added strength to the sand subgrade since the test sections with the sand reinforced with these materials sustained more traffic than when there were no reinforcements (see Incl 83 for summary of passes and rut depths). However, since these materials failed during this investigation and were considered ineffective in adequately confining the sand, no further tests are recommended.

d. The aluminum 6-in. hexagon cell, 8 in. depth grid with and without membrane provided more strength to the sand subgrade than did the other grids and membrane combinations. This grid with and without membrane sustained 1000 passes of the M54 truck and was still traffickable. The rut depth of this grid with and without membrane after 1000 passes was only 4.6 and 4.9 in. The rut depths for the unsurfaced sand and other grid/membrane combinations used for reinforcement were much greater (Incl 83). However, except for the aluminum 6-in. hexagon cell, 6-in. depth grid, the other materials had failed at 1000 passes or less. Although the rut depth for the aluminum 6-in. cell 6-in. depth grid with and without membrane after 1000 passes of traffic was 7.2 and 7.7 in., these materials remained traffickable. The rut depth at which the undercarriage of the M54 drags the subgrade and becomes immobile is between 11 and 12 in.

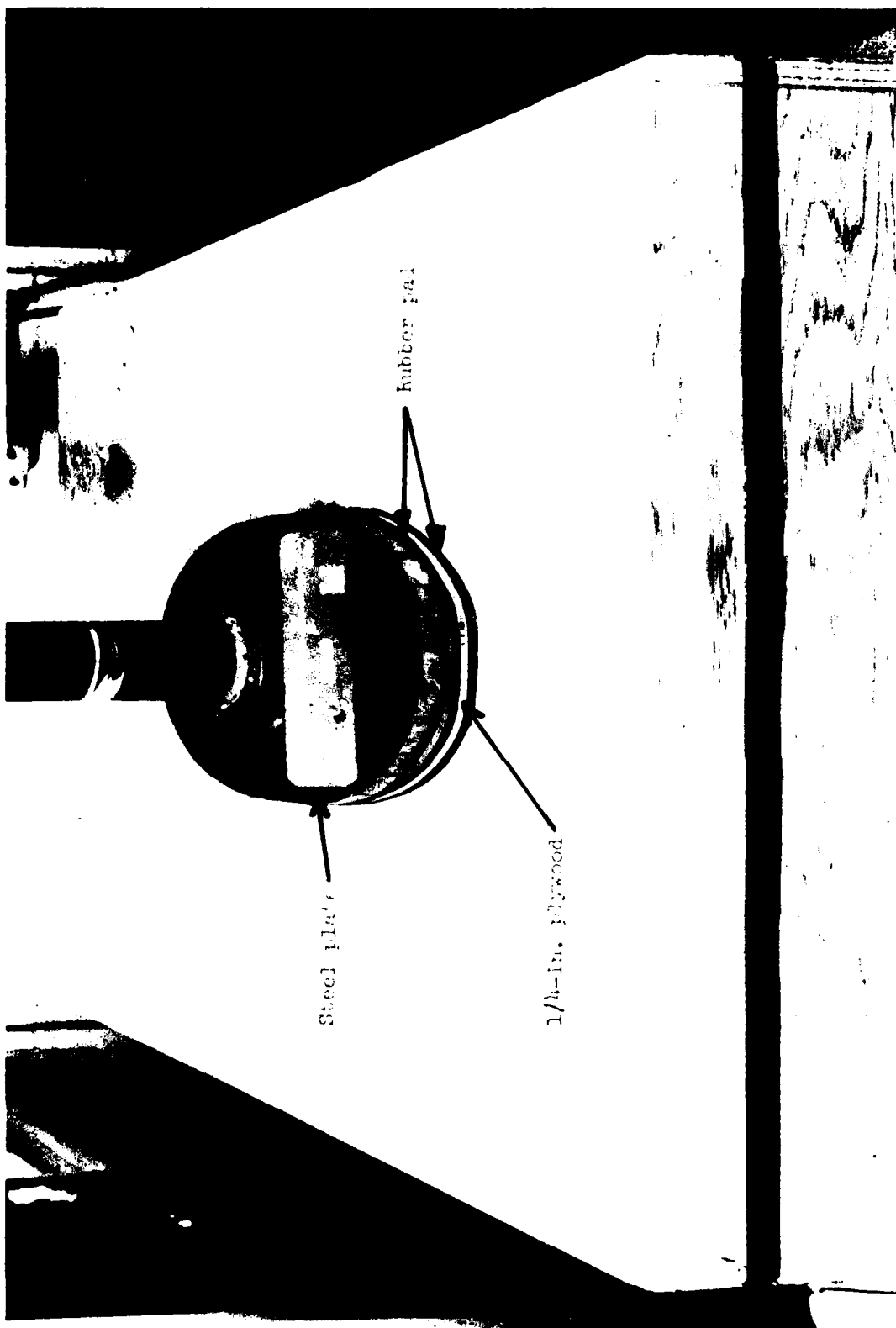
e. It is recommended that traffic tests with the M54 cargo truck with highway loading conditions (40,000 lb gross weight) and tires inflated to 70 psi be conducted on aluminum 6-in. hexagon cell, 6 and 8 in. depth grids both with and without Kevlar membrane placed on a loose sand subgrade and a weak (1-2 CBR) clay subgrade with the cells filled with loose sand in order to fully evaluate these materials for bridge access/egress application.

83 Incl
as

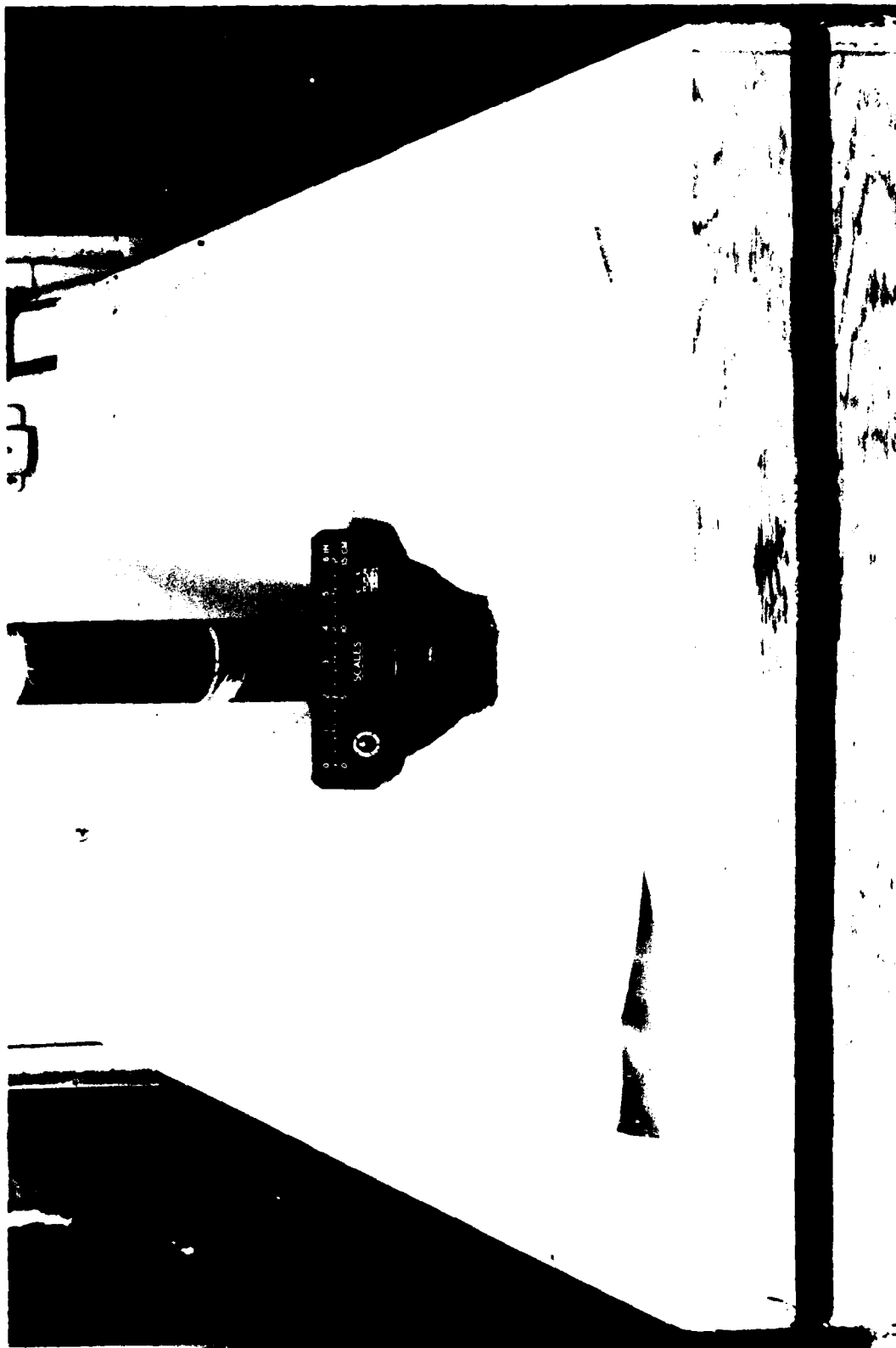
Devey W. White Jr
DEVEY W. WHITE, JR.
Landing Mat Branch
Materiel Development Division



6 inch aluminum cell grid, 6 inches deep prior to filling with sand for laboratory tests



Laboratory Test Set-Up Prior to Test



Failure of aluminum grid in laboratory test

Incl 3



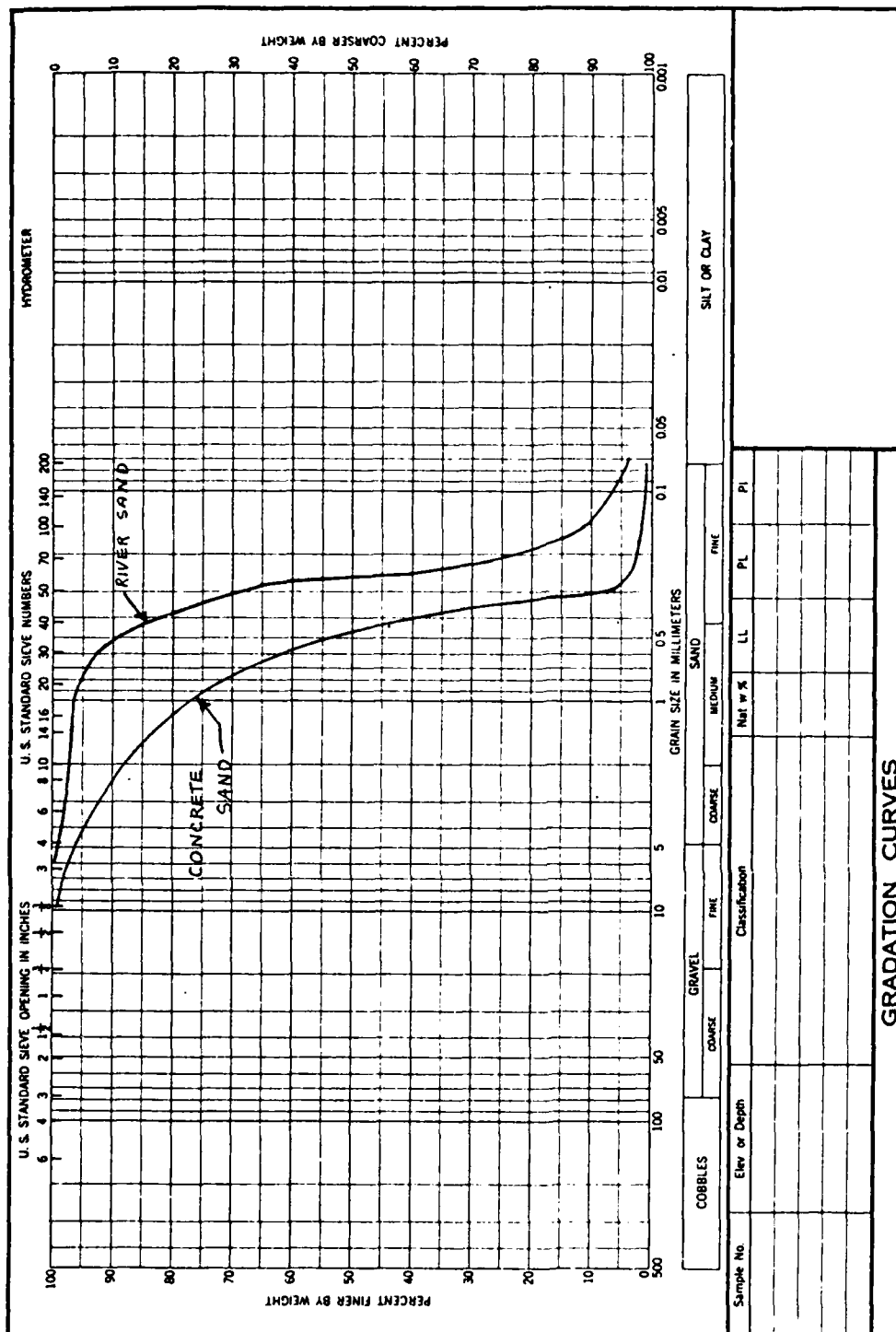
Aluminum grid after laboratory tests

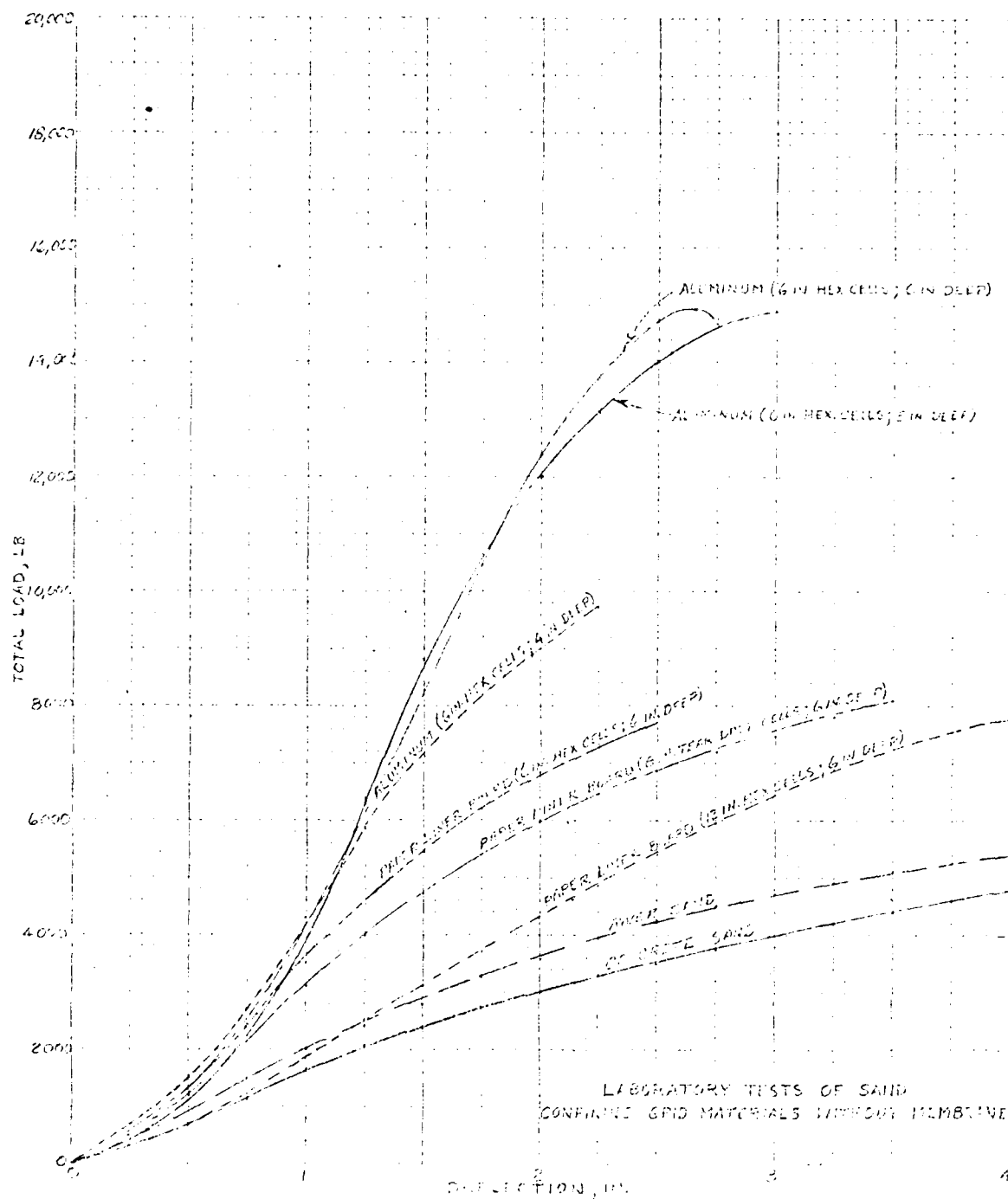


Membrane failure in laboratory tests

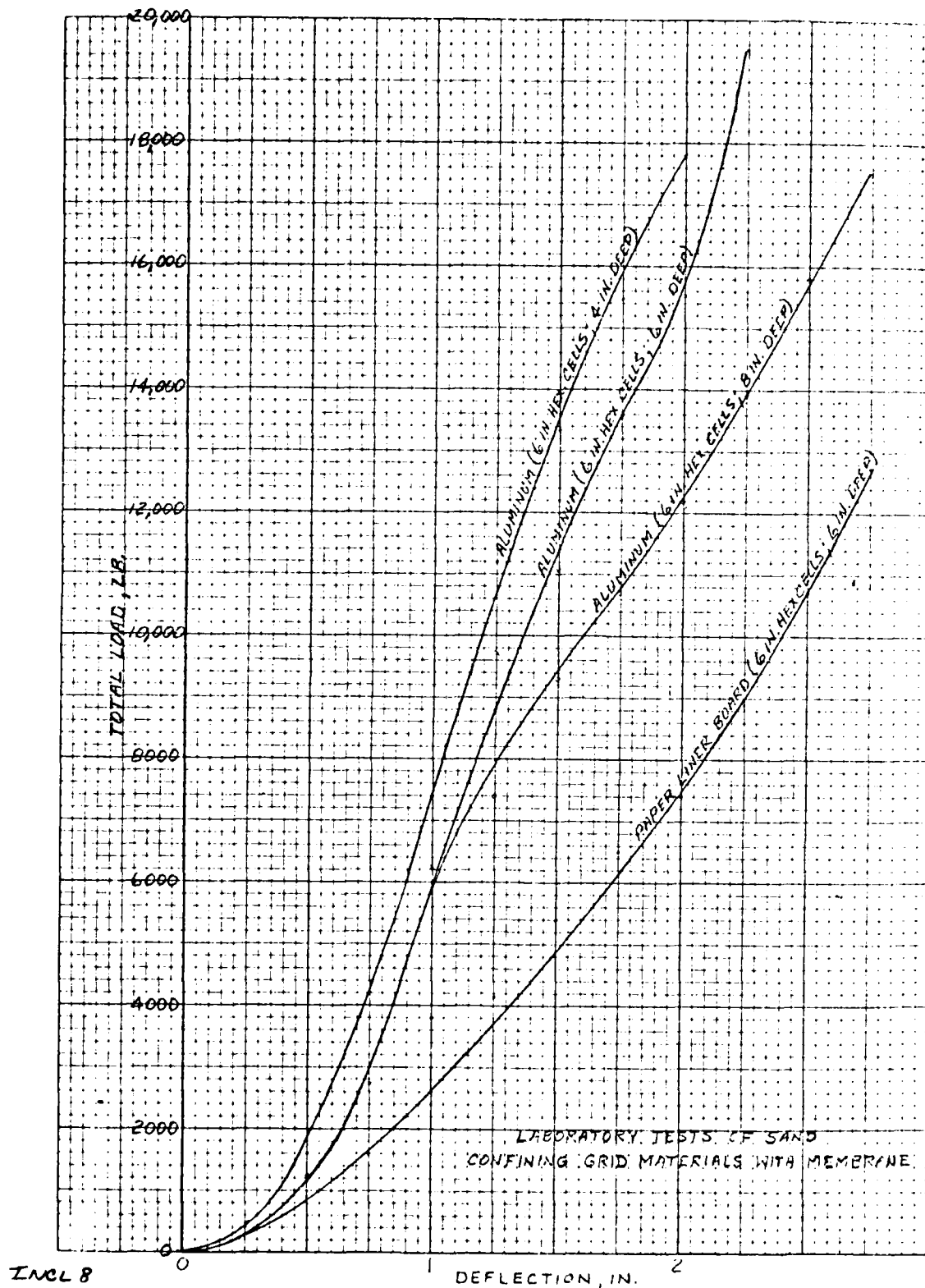
Incl 5

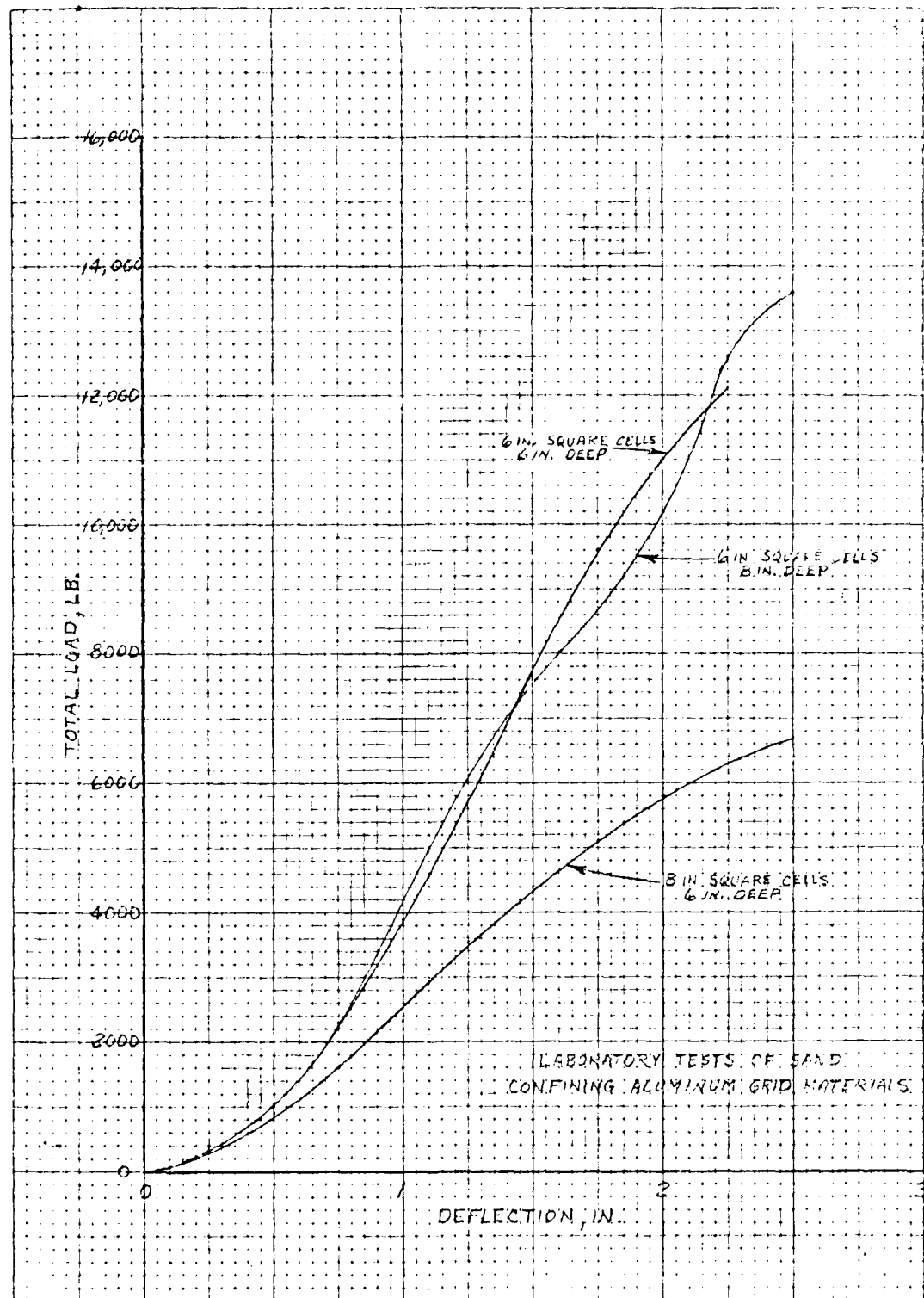
211





INCL 7





INCL 9

Fabric Testing

Product: Kevlar Fiber - B (DE 8473)

Manufacturer: Reeves Brothers, Inc.

Test and Unit of Measure	Test Method	Test Results
Weight, oz per sq yd	Fed. Test Method Std. No. 191, Method 5041	15.55
Thickness, inches	Fed. Test Method Std. No. 191, Method 5030	.013
Breaking Strength, Grab, lb	ASTM D-1682-64	Warp - 573 Fill - 440
Apparent Elongation @ Break, %	ASTM D-1682-64	Warp - 6 Fill - 7
Tear Strength, Tongue, lb	ASTM D-2261	Warp - 60 Fill - 49
Bursting Strength, Ball, psi	ASTM D-751-72	263
Joint Strength, lb		740

Note: All breaks were in fabric; no breaks in joint

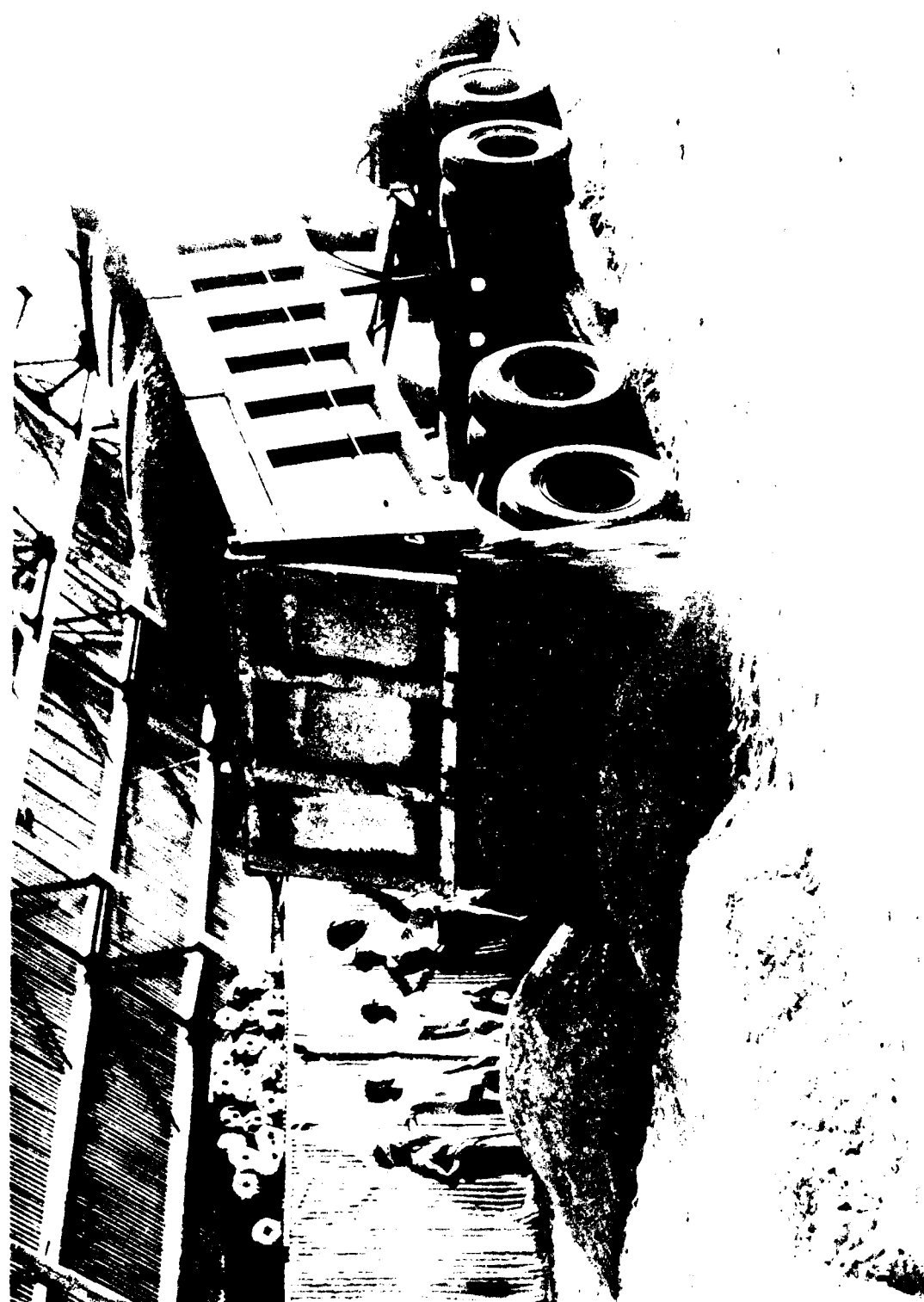
Incl 11

Summary of Laboratory Grid Tests

Cell Size, in.	Cell Depth, in.	Material	Cell Type	Membrane	Deflection @ 6000 lb load, in.	Rating Based on Deflection @ 6000 lb load	Rating Based on Load at 2 in. of Deflection, lb	Rating Based on Load at 2 in. of Deflection
6	4	Aluminum	Hexagon	Without	1.28	5	9,100	8
6	4	Aluminum	Hexagon	With	0.90	1	17,800	1
6	6	Aluminum	Hexagon	Without	1.20	3	12,400	3
6	6	Aluminum	Hexagon	With	1.00	2	15,800	2
6	6	Aluminum	Square	Without	1.29	6	11,000	6
6	8	Aluminum	Hexagon	Without	1.24	4	12,000	5
6	8	Aluminum	Hexagon	With	1.00	2	12,200	4
6	8	Aluminum	Square	Without	1.24	4	10,200	7
8	6	Aluminum	Square	Without	2.10	10	5,800	12
6	6	Paper	Hexagon	Without	1.68	7	6,800	10
6	6	Paper	Hexagon	With	1.72	8	7,500	9
8	6	Paper	Tear Drop	Without	2.00	9	6,000	11
12	6	Paper	Hexagon	Without	2.75	11	4,300	13
-	-	Concrete Sand	-	-	4.00*	13	3,000	15
-	-	River Sand	-	-	4.00**	12	3,600	14

* Deflection @ 4800 lb load (did not reach 6000 lb)

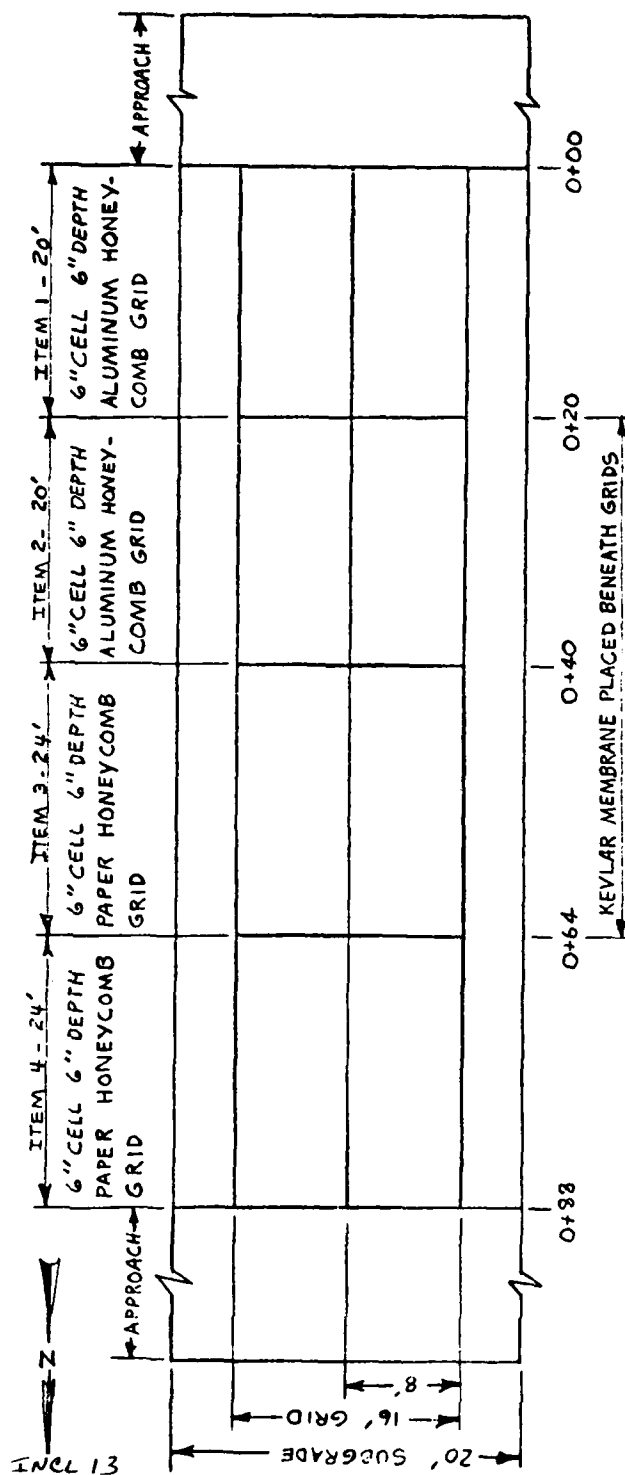
** Deflection @ 5400 lb load (did not reach 6000 lb)



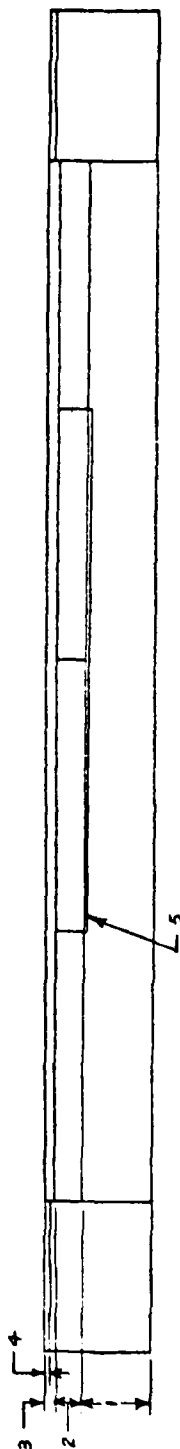
Sand being placed during construction of the test section

Incl 12

218



PLAN



- 1 - 12" SAND SUBGRADE
- 2 - 6" GRID FILLED WITH SAND
- 3 - 2" SAND OVER FILL
- 4 - USED LANDING MAT PLACED ON SAND SUBGRADE
- 5 - KEVLAR MEMBRANE

PROFILE

TEST SECTION LAYOUT

6" CELL 6" DEPTH PAPER AND ALUMINUM GRIDS WITH/WITHOUT MEMBRANE



Membrane placed on sand subgrade prior to placement of grid materials

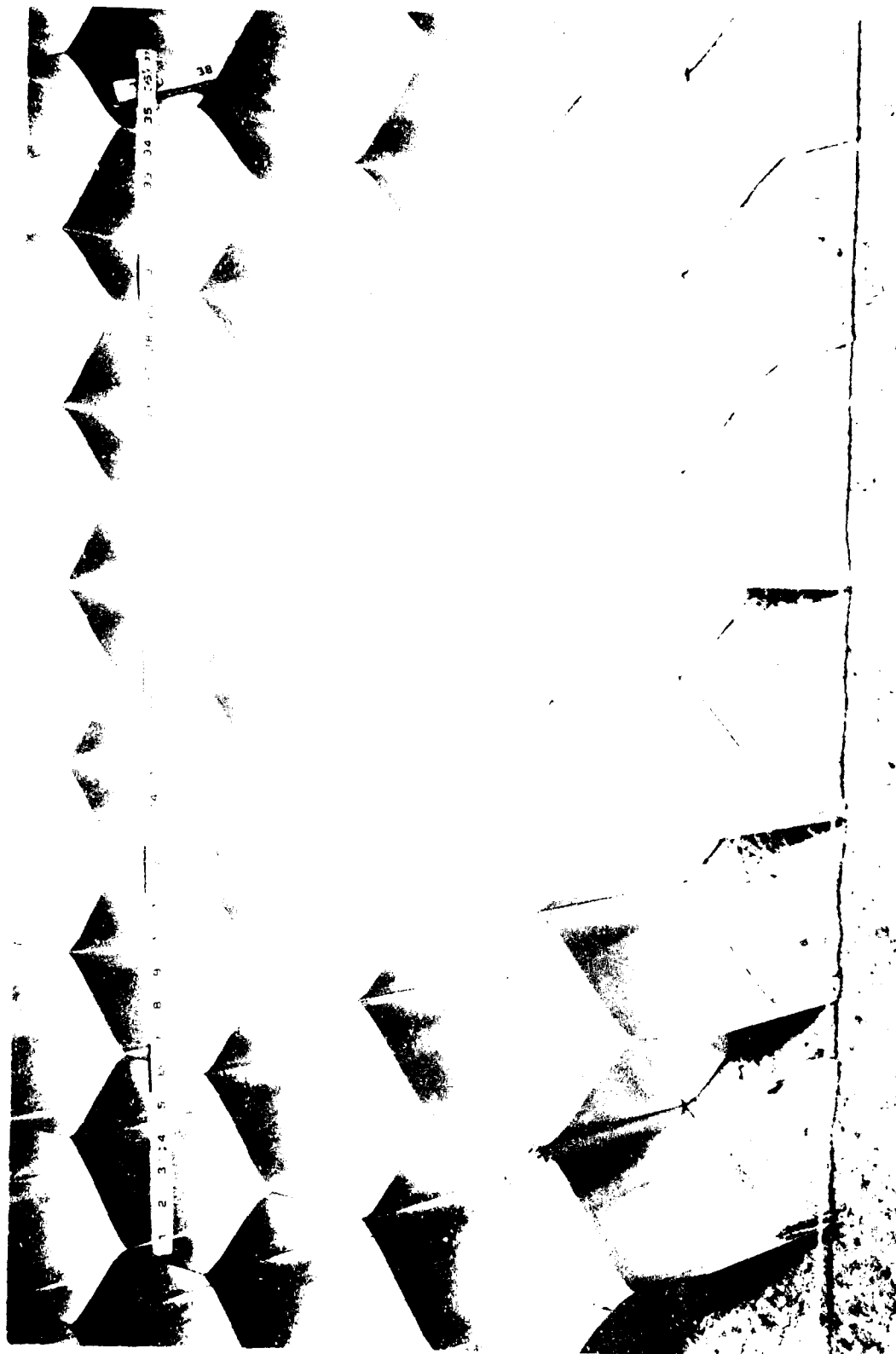
Incl 15

221

Slab of 6 inch cell 6 inch deep aluminum grid prior to expansion



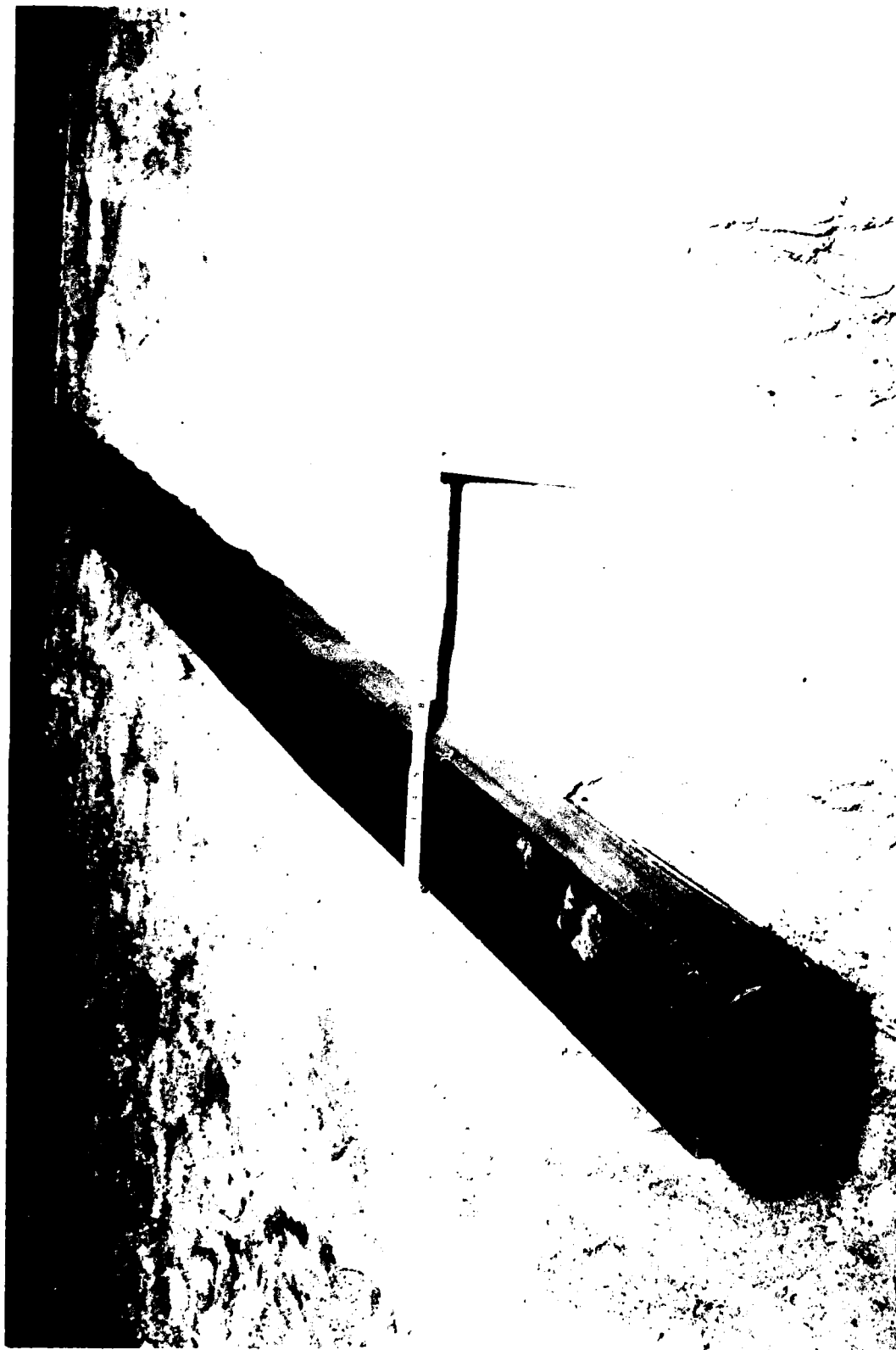
Aluminum grid being expanded during placement



Close up of aluminum grid after expansion

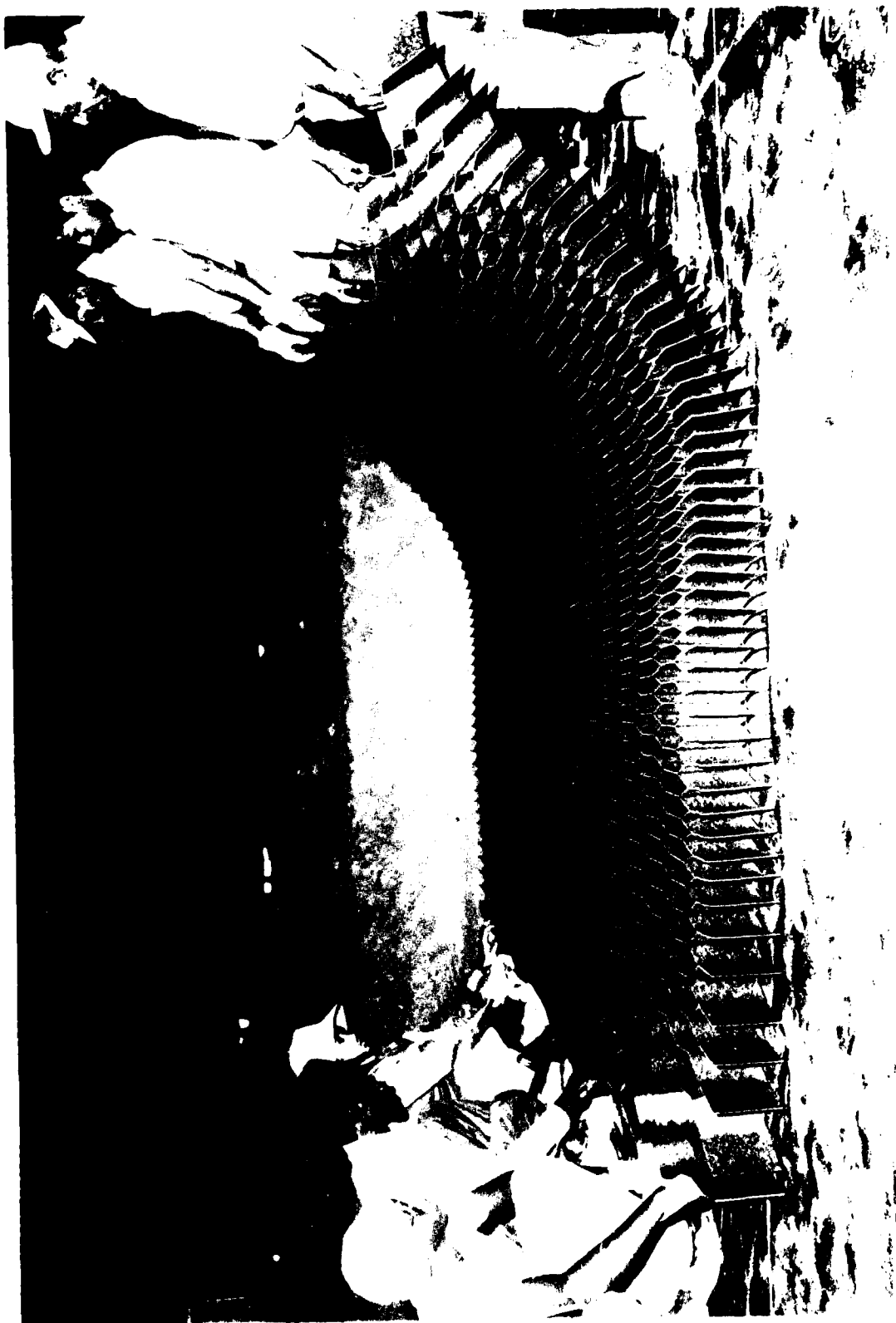
Incl 17

223



Slab of 6 inch cell, 6 inch deep paper grid prior to expansion

Incl 18



Paper grid being expanded during placement

Incl 19

225



Aluminum and paper grids after placement on test section but
prior to being filled with sand



Completed test section prior to traffic

Incl 2

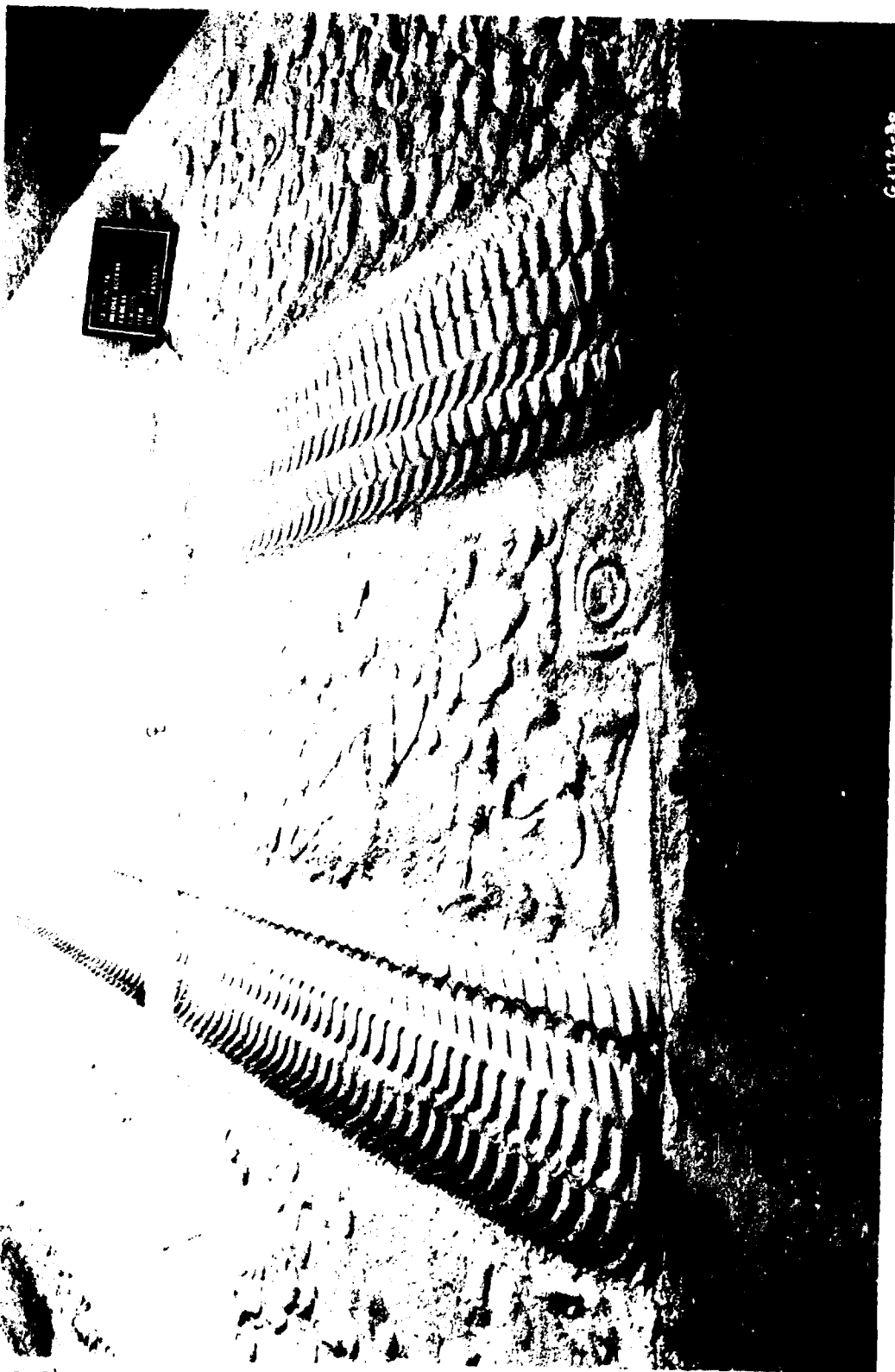


M54 cargo truck used in traffic test



Test section after 10 passes of traffic

Incl 23

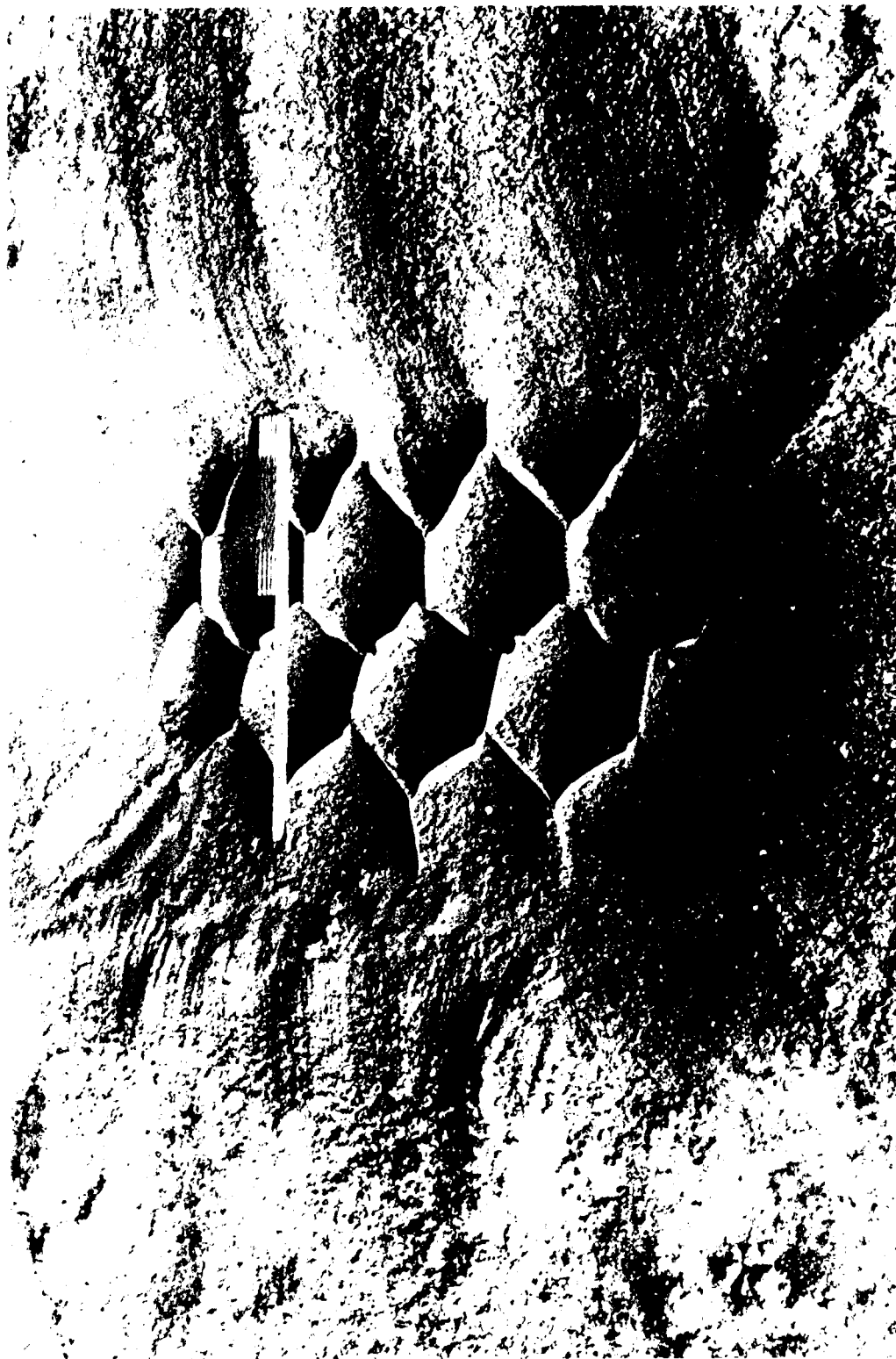


G112-30

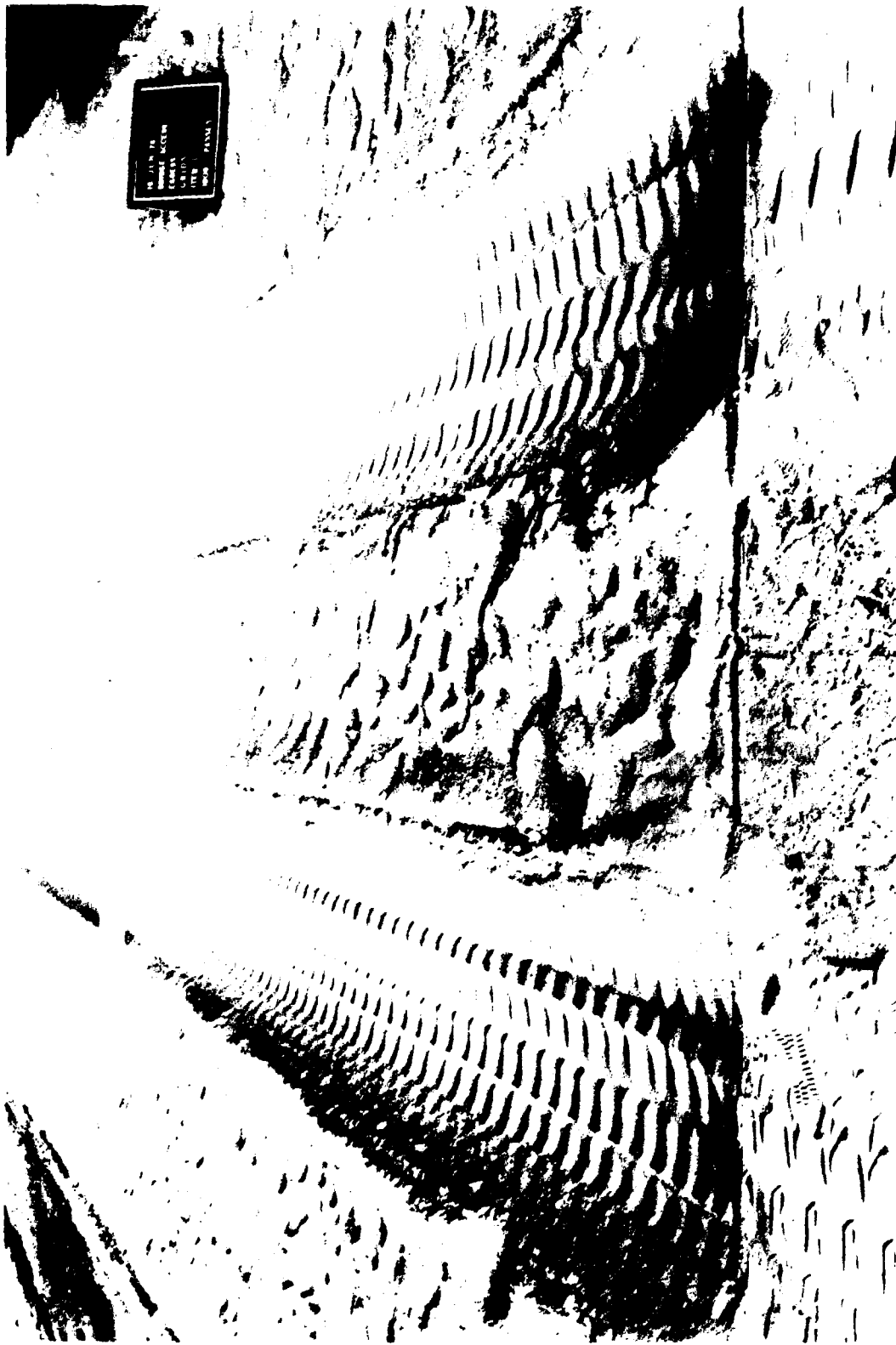
Item 1 after 10 passes

Incl 24

230



Grid in item 1 after 10 passes



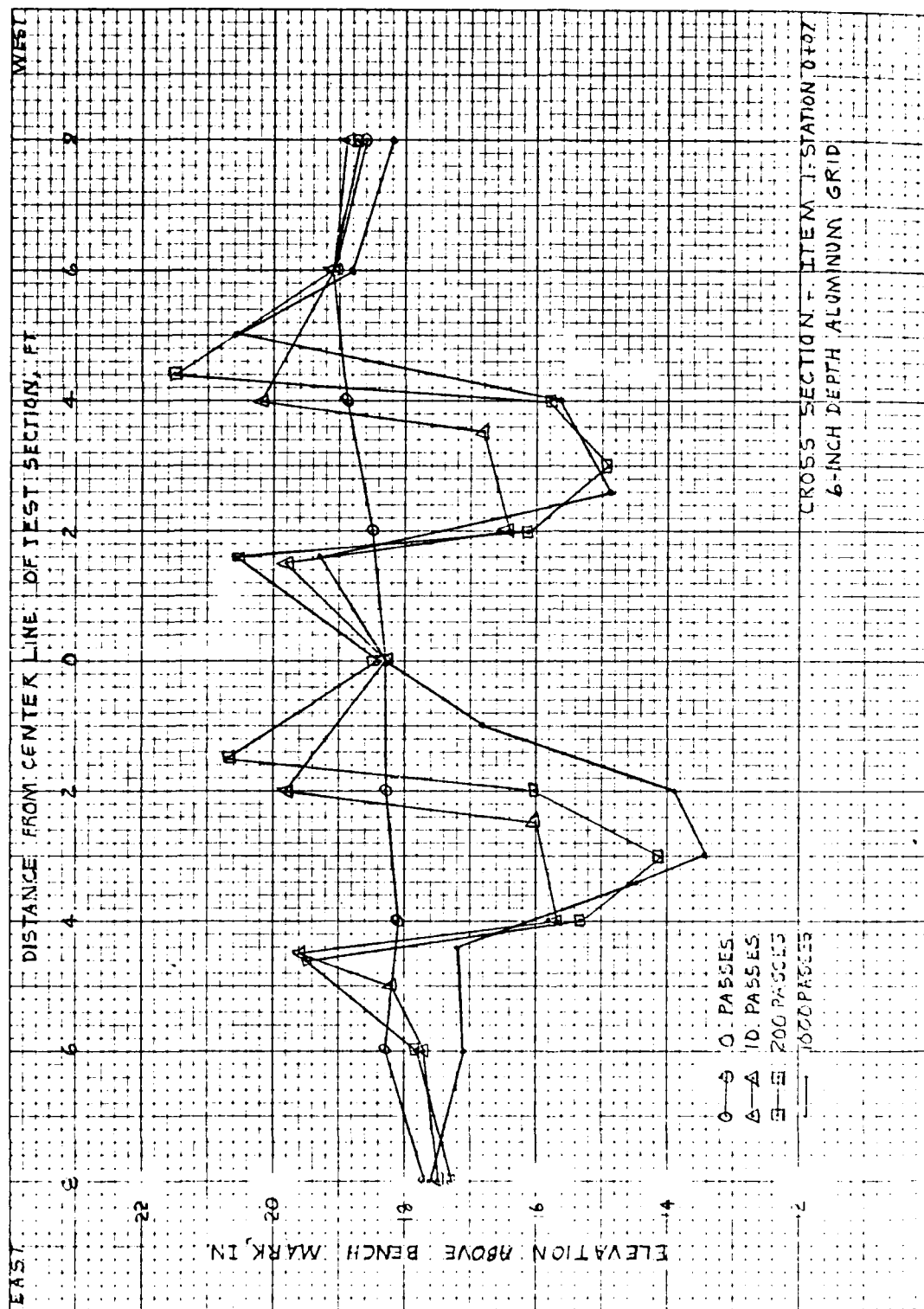
Item 1 after 1000 passes

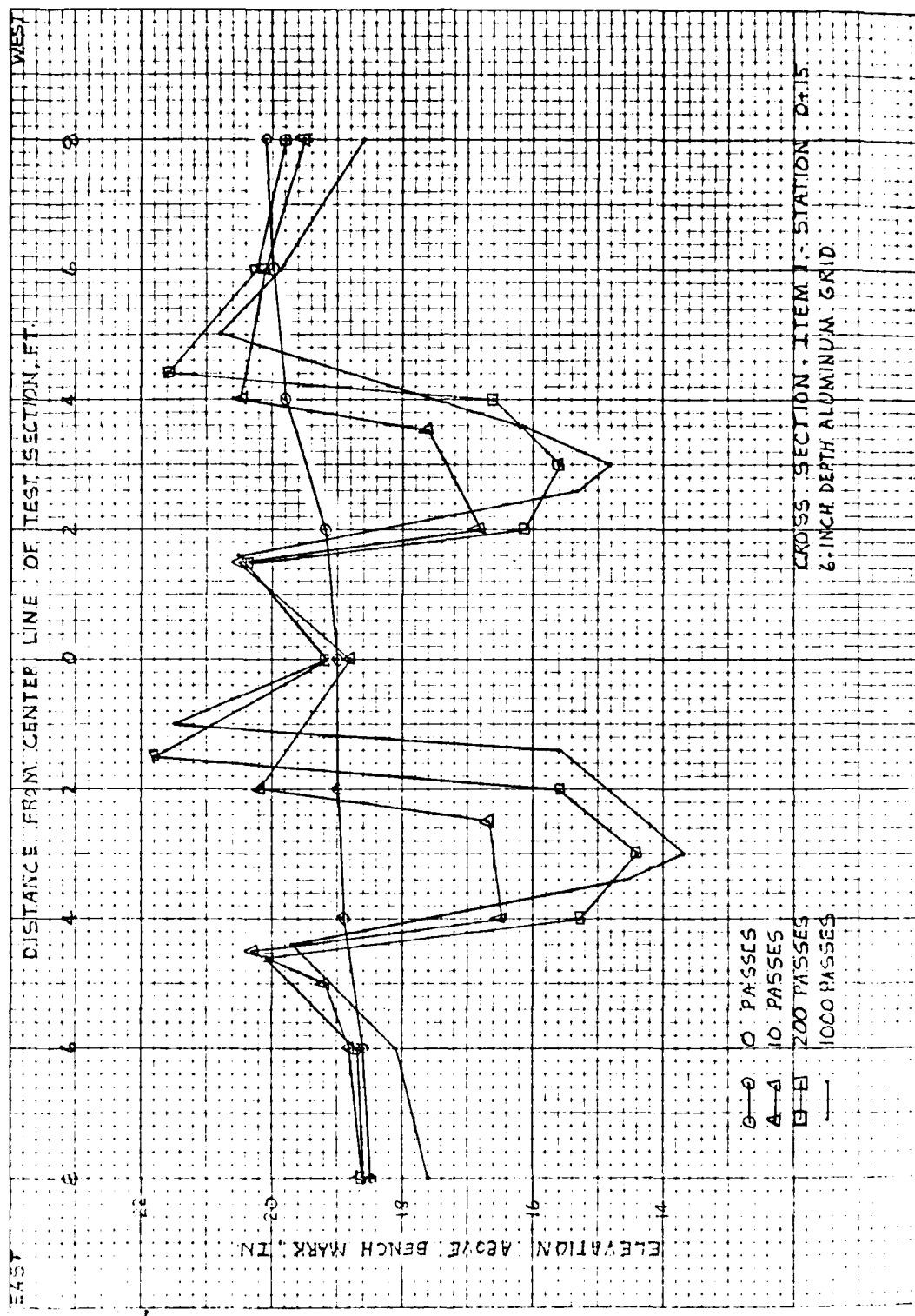
Incl 26

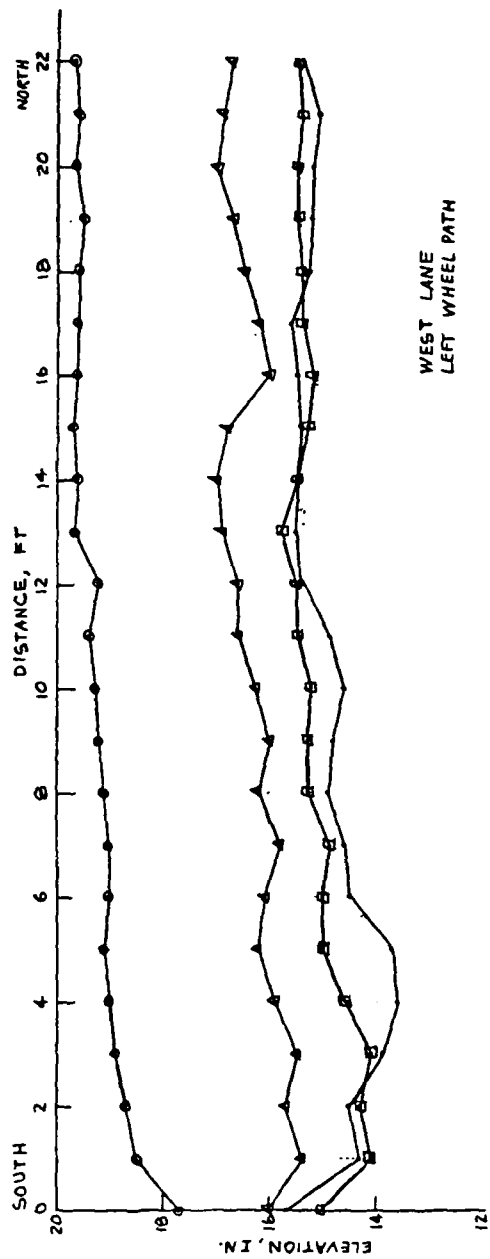
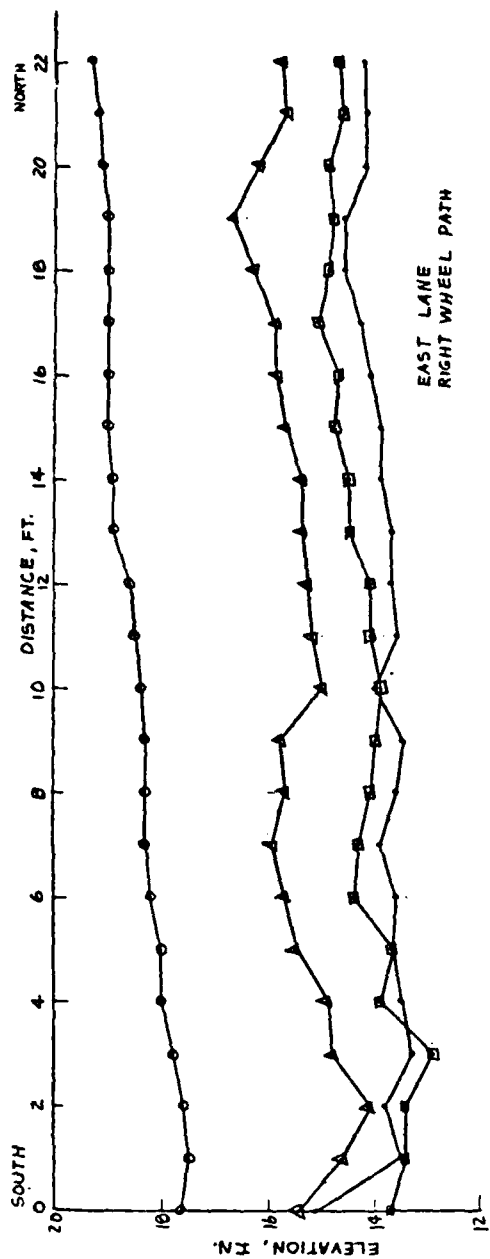
232



Grid in item 1 after 1000 passes

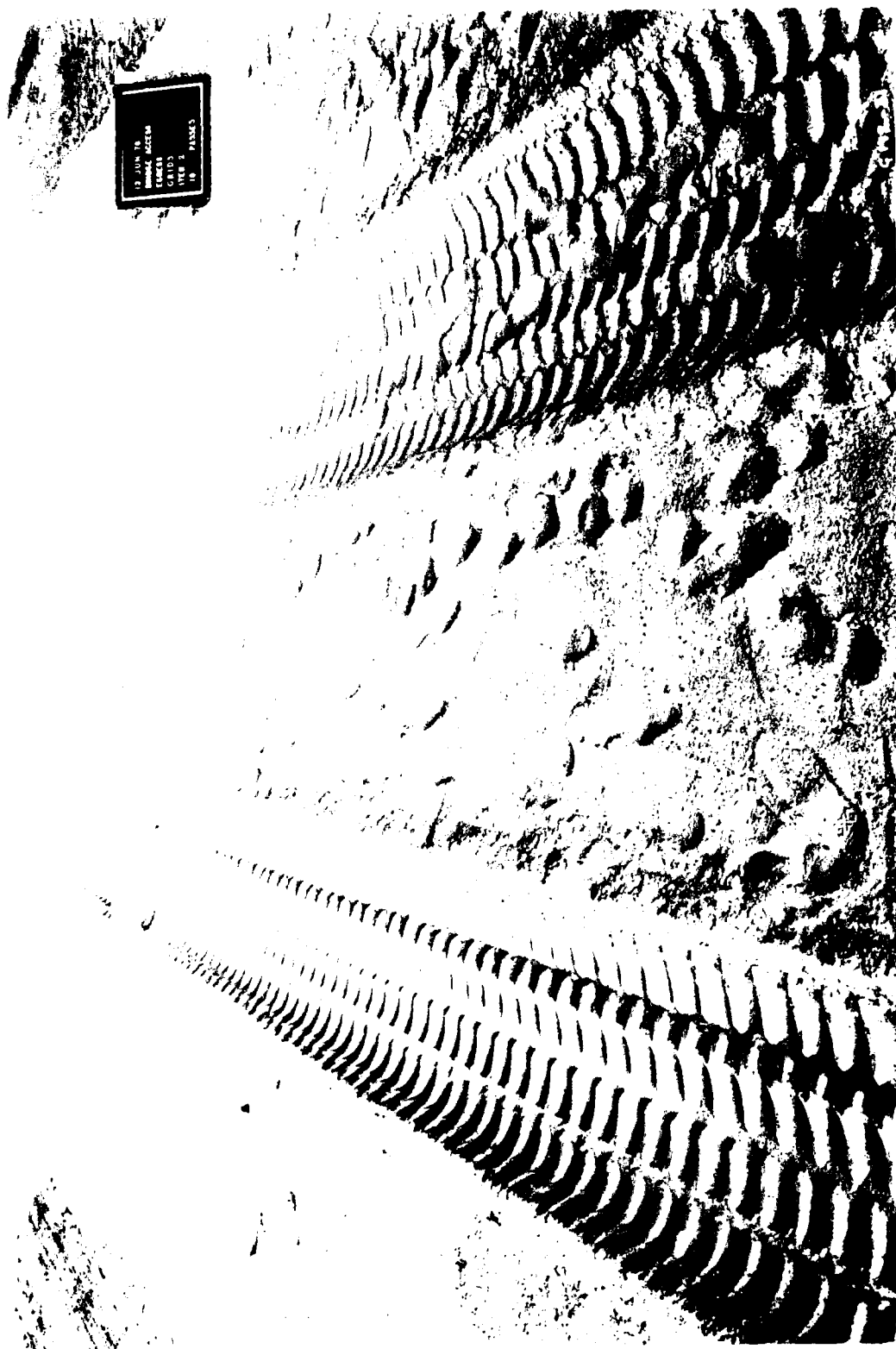






PROFILE - ITEM 1
6-INCH DEPTH ALUMINUM GRID

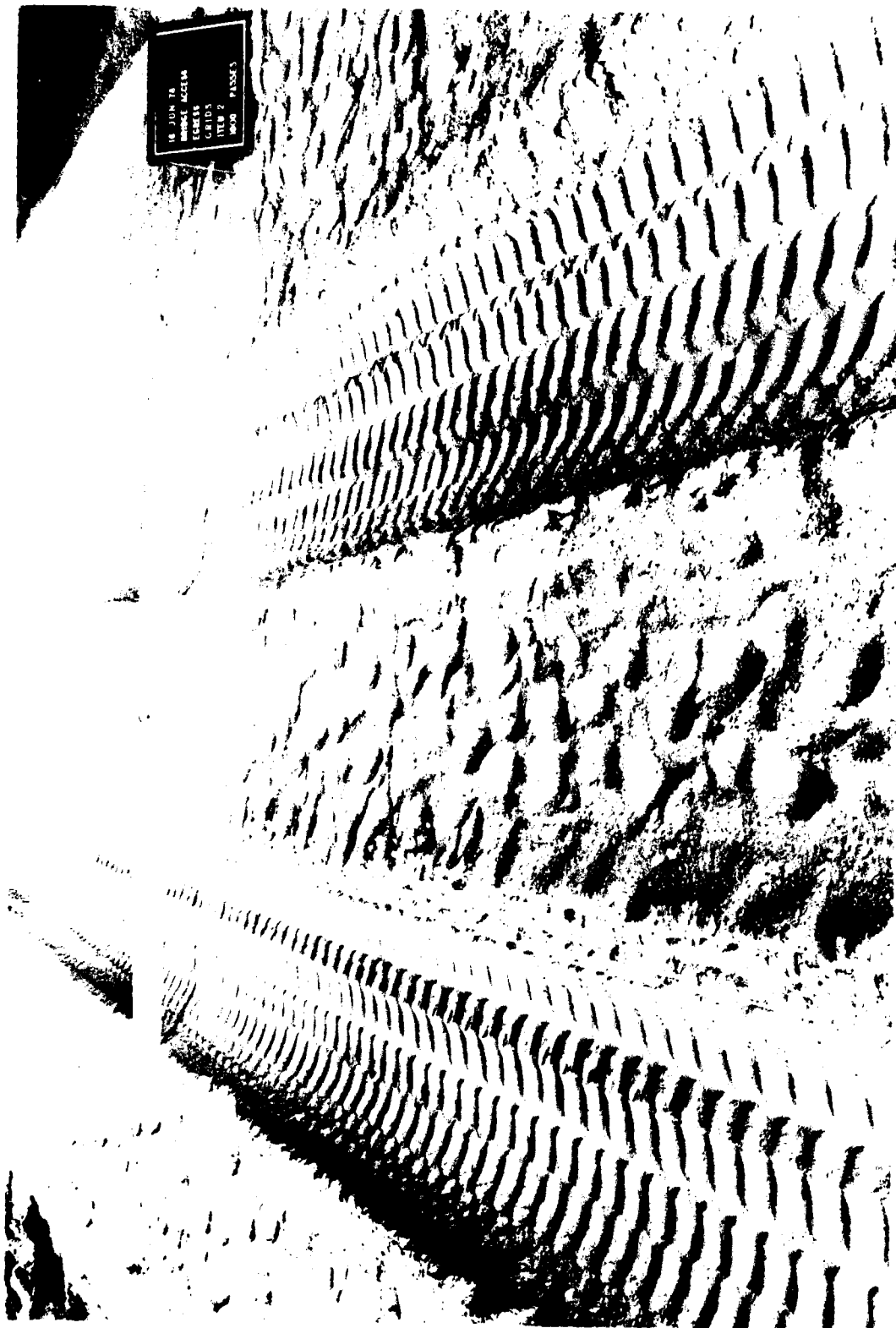
○ 0 PASSES
△ 10 PASSES
□ 200 PASSES
◇ 1000 PASSES



Item 2 after 10 passes

Incl 30

237



16 JUN 74
PROJECT ACCEL
CROSS
SITE 2
1000 - 1000

Item 2 after 1000 passes

Incl 31

238

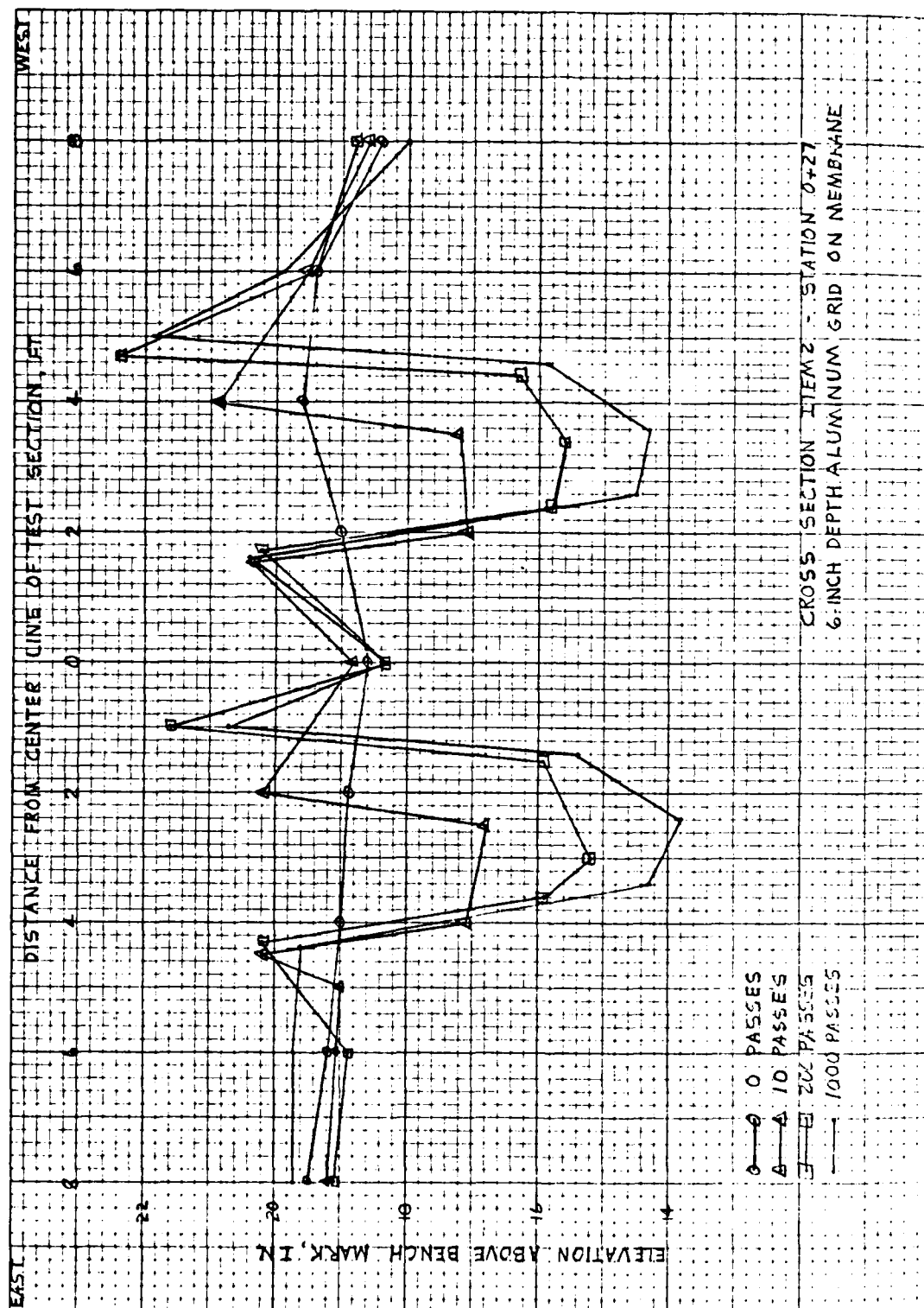
Incl 32

239

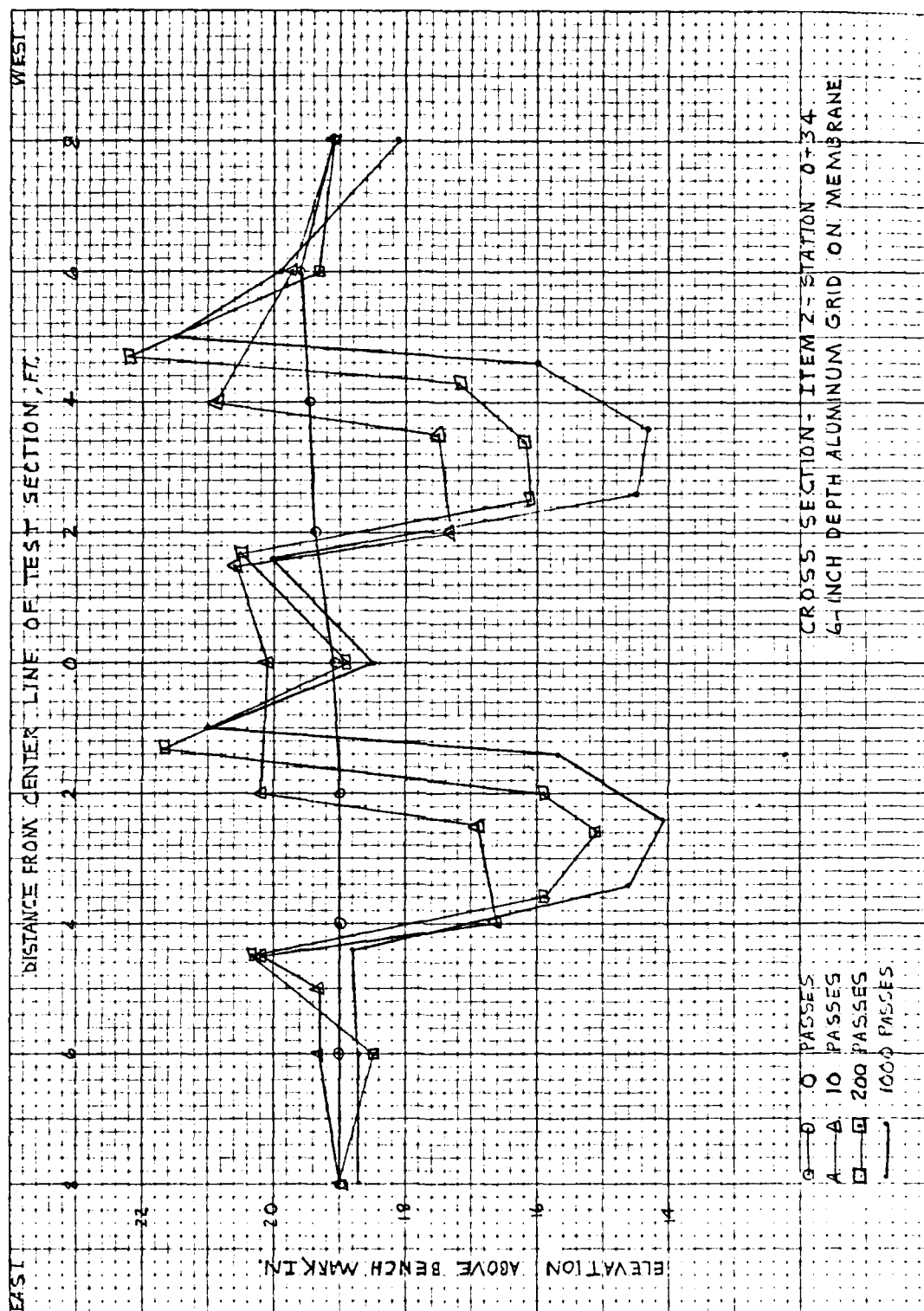
Grid in item 2 after 1000 passes

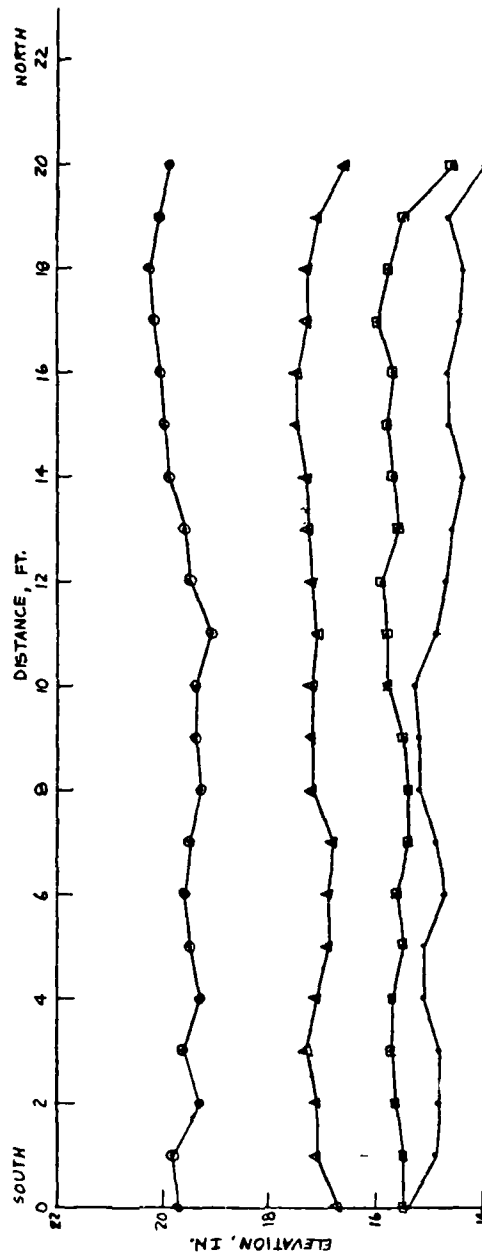
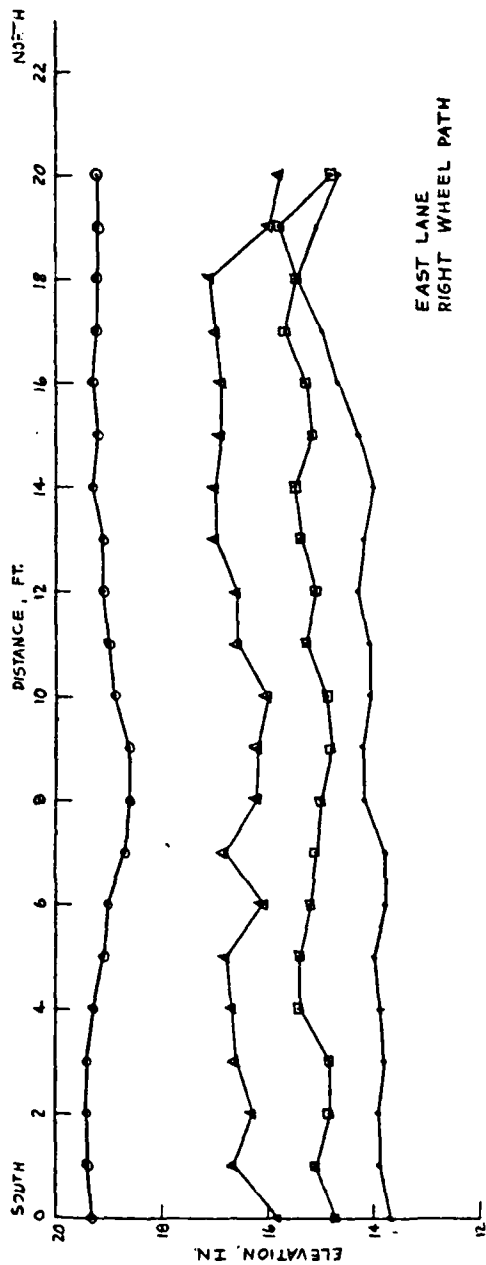


INCL 33 PAGE 1



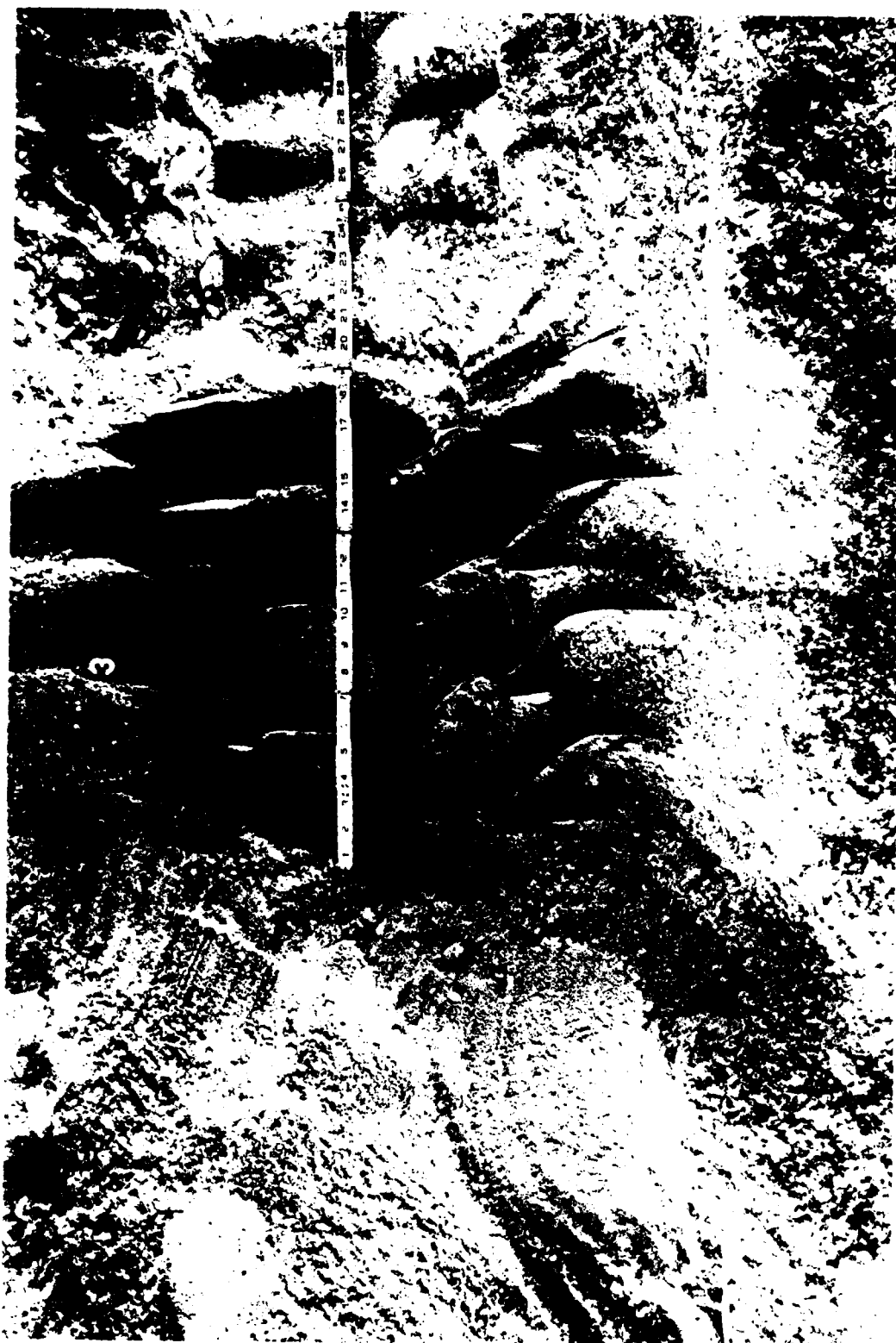
INCL 33 PAGE 2



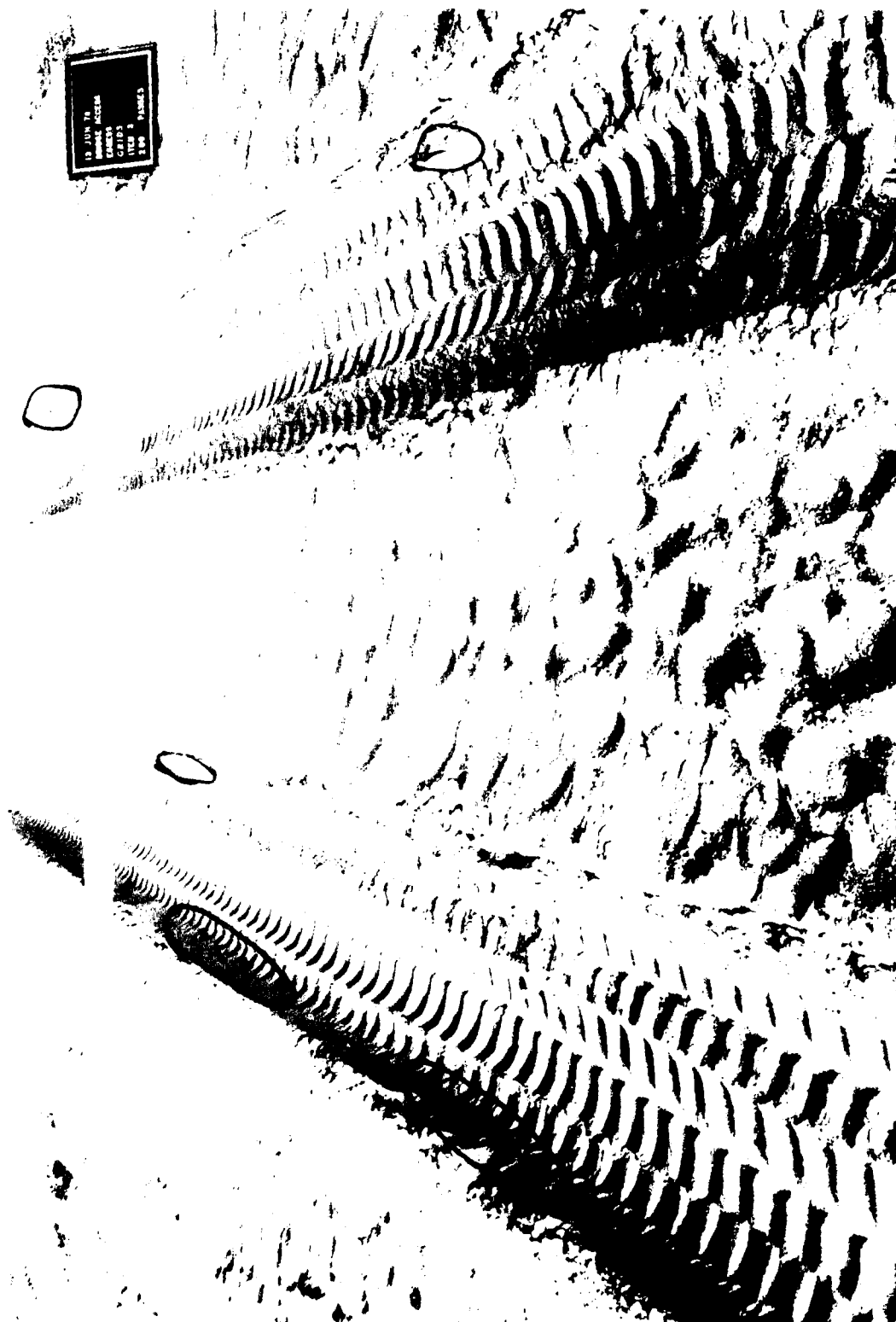


○—○ 0 PASSES
 △—△ 10 PASSES
 □—□ 200 PASSES
 ◇—◇ 1000 PASSES

PROFILE - ITEM 2
 6-INCH DEPTH ALUMINUM GRID ON MEMBRANE



Grid in item 3 after 10 passes



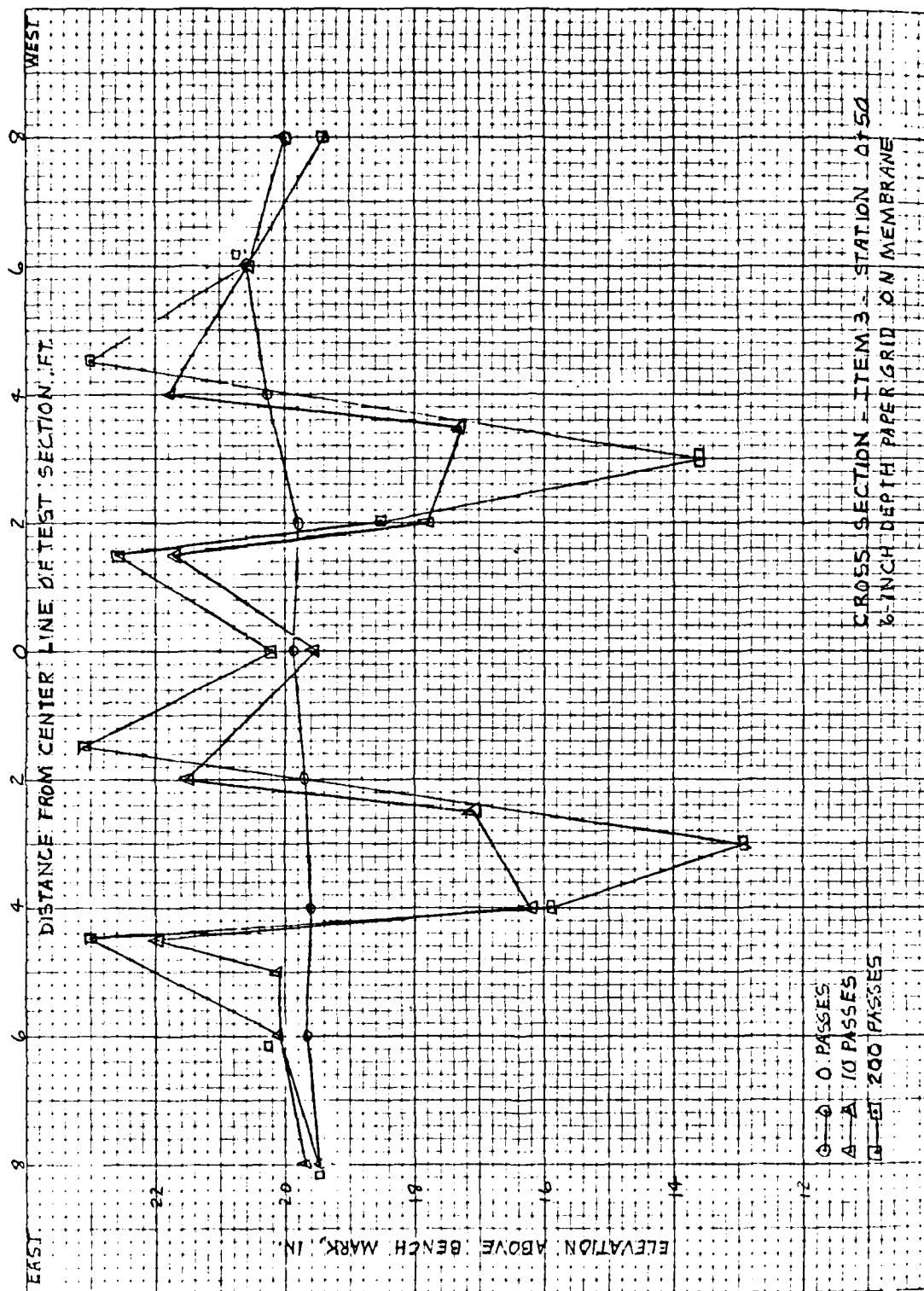
13 JUN 78
HAWAIIAN ISLANDS
CROSSING
ITEM 3
100 110000

Item 3 after 200 passes

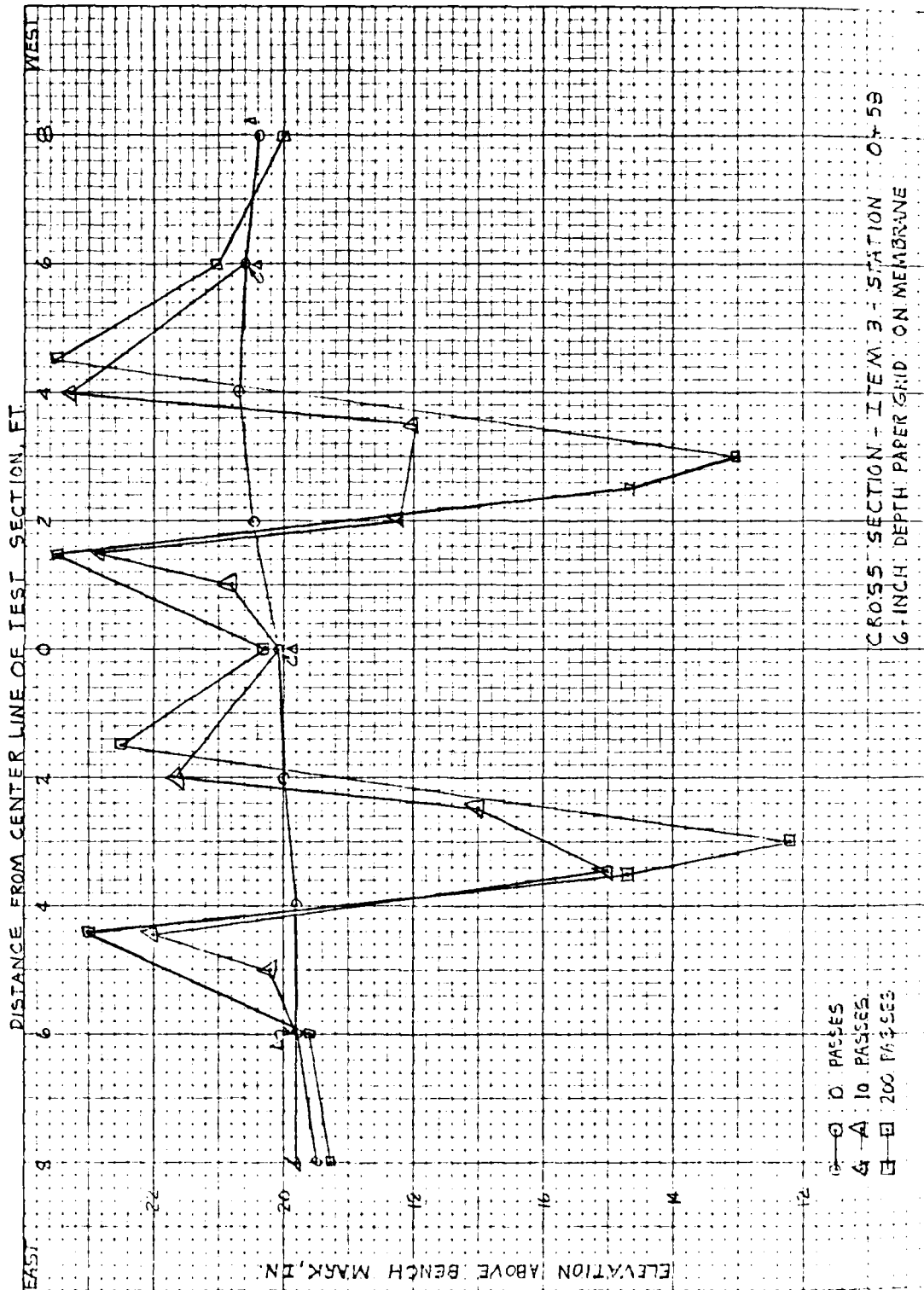
Incl 37

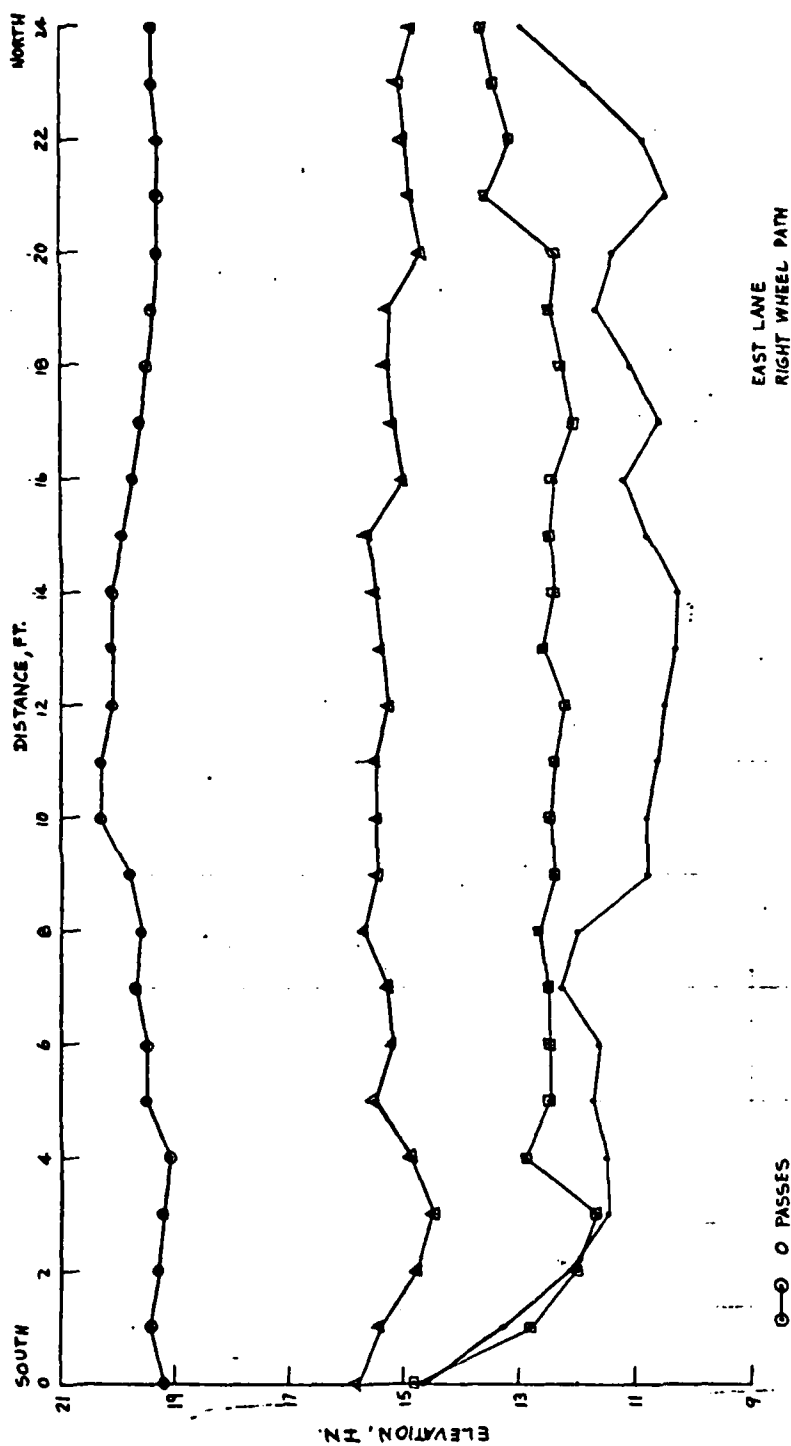
245

INCL 38 PAGE 1



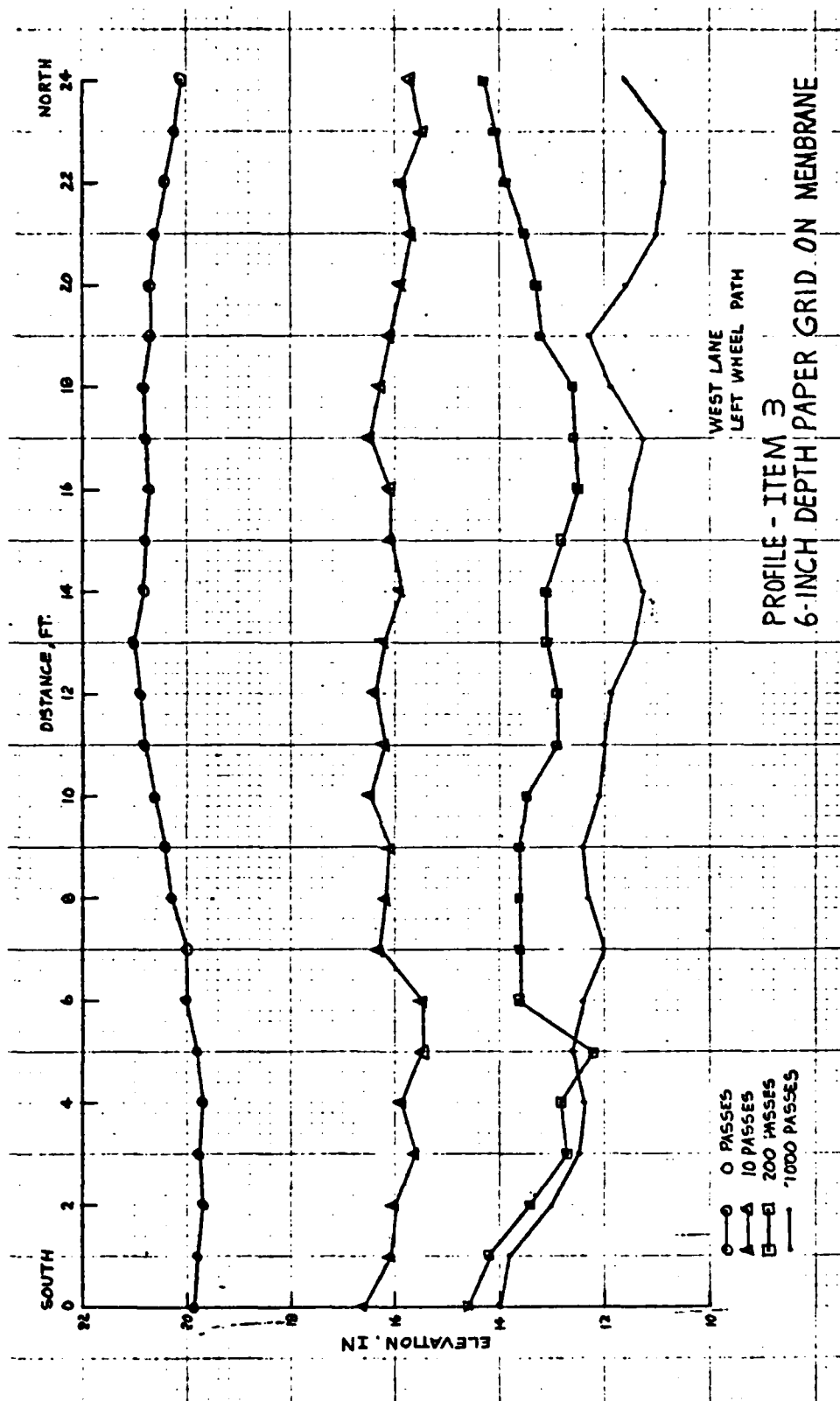
INCL 38 PAGE 2

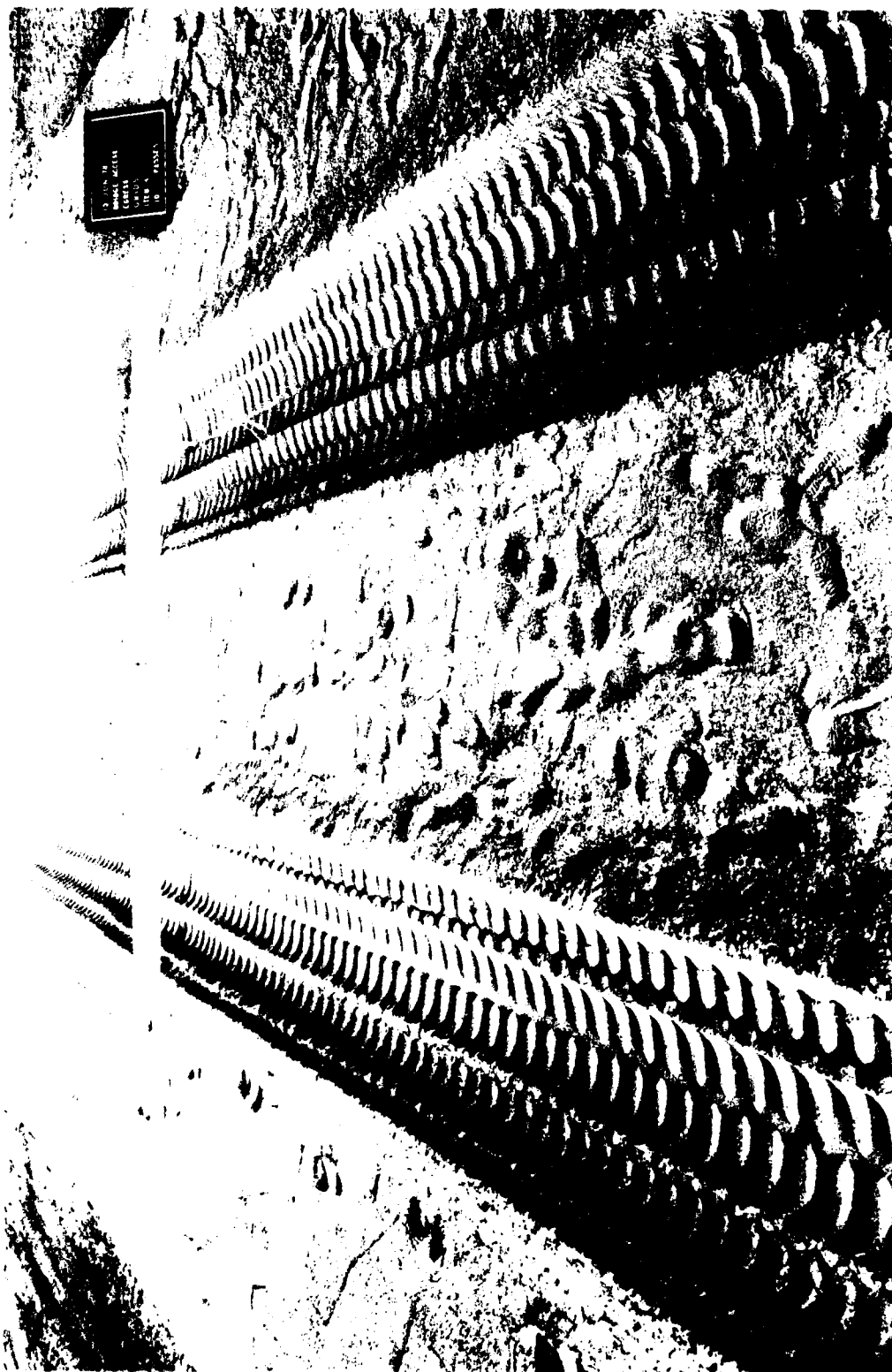




EAST LANE
RIGHT WHEEL PATH

PROFILE - ITEM 3
6-INCH DEPTH PAPER GRID ON MEMBRANE





Item 4 after 10 passes

Incl 40

250



Grid in item 4 after 10 passes

Incl 41

251

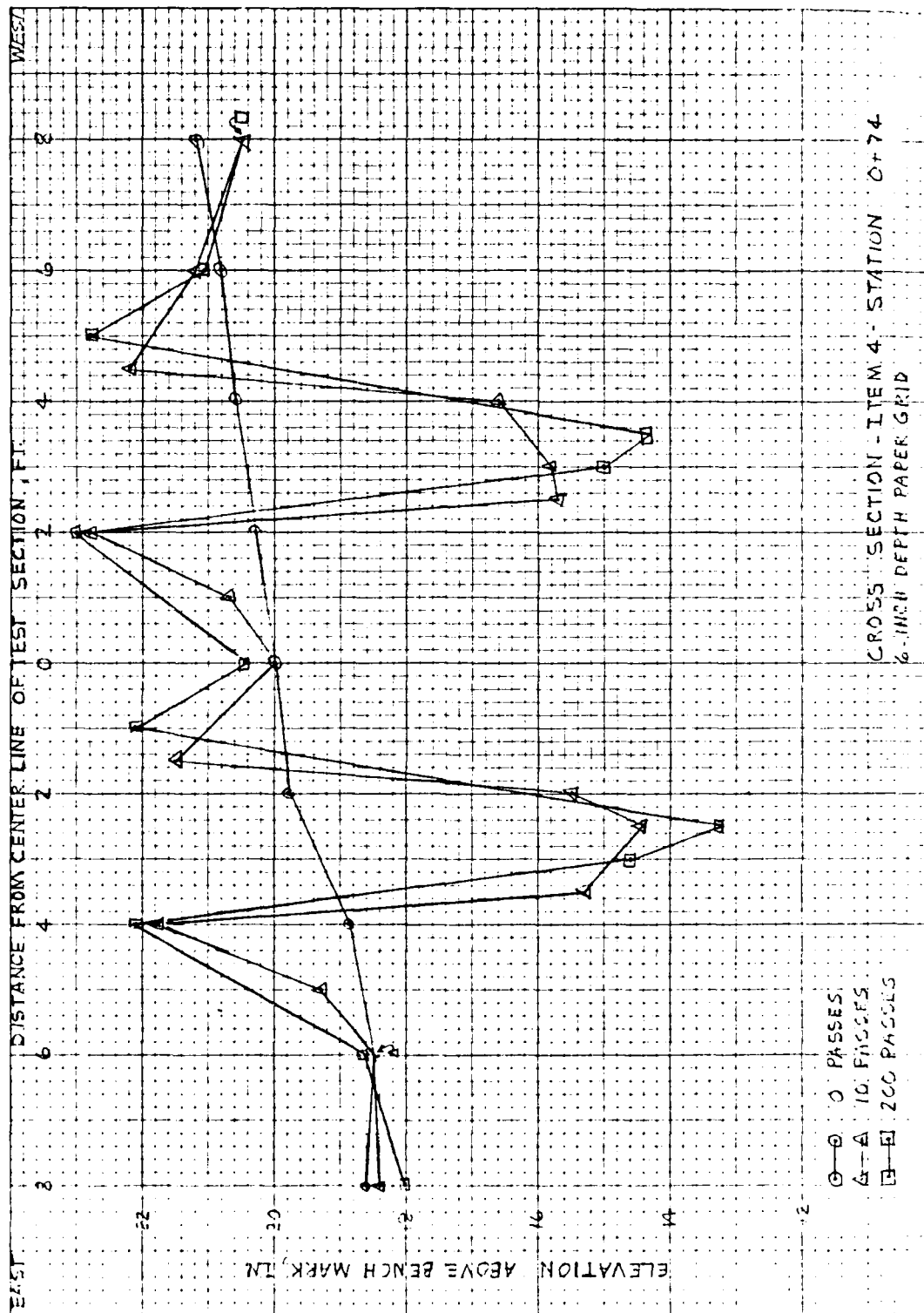


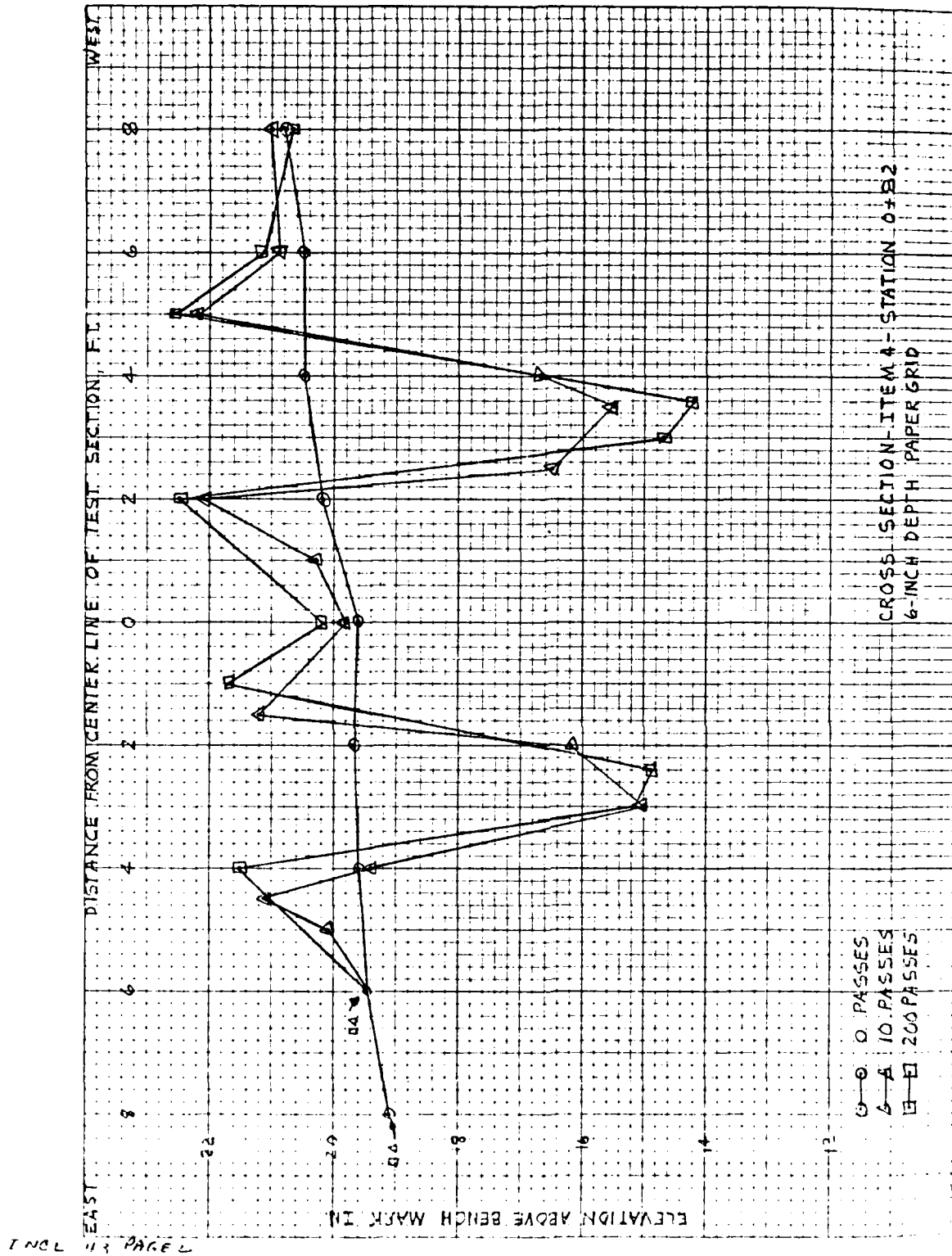
Item 4 after 200 passes

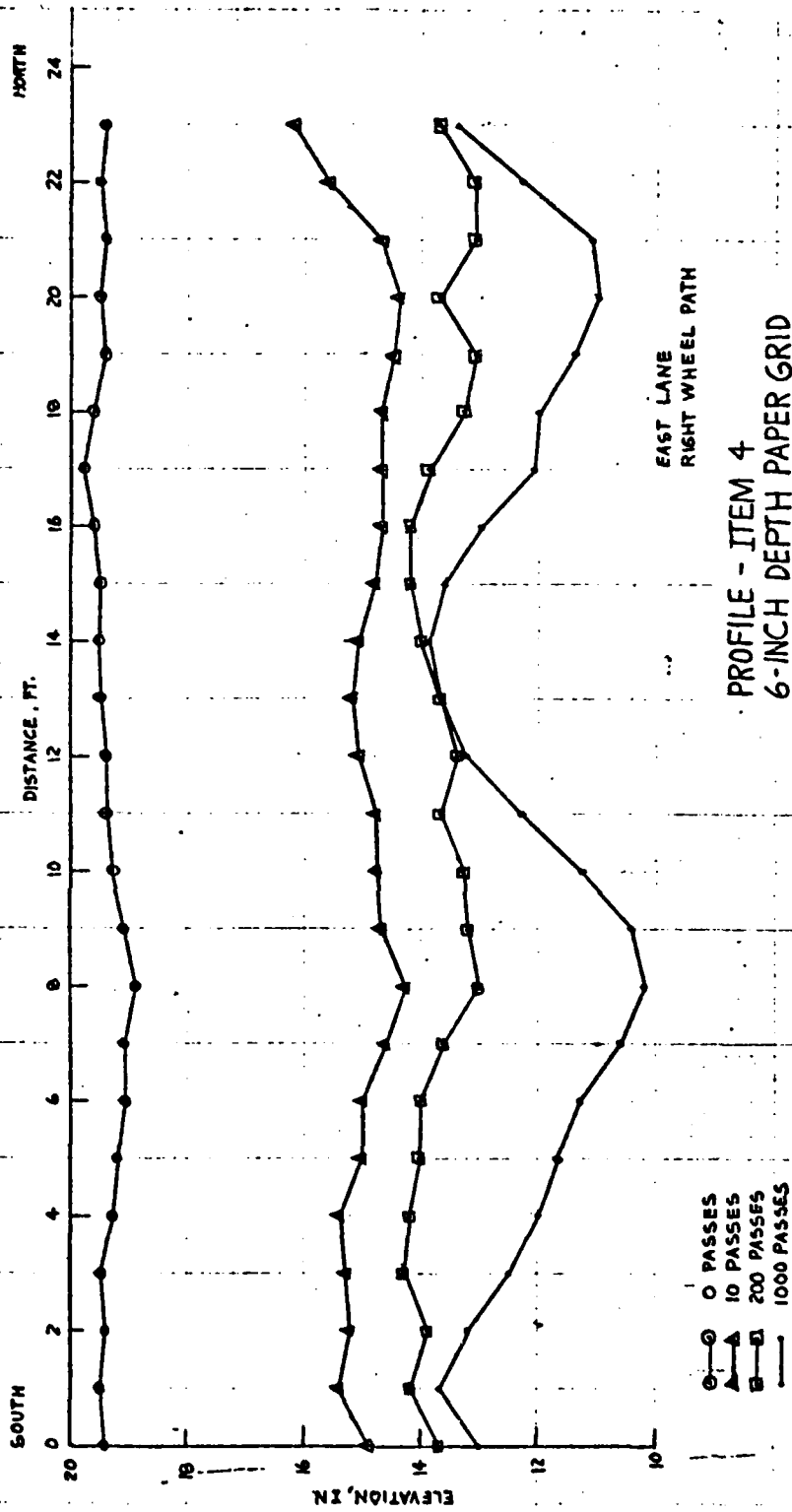
Incl 42

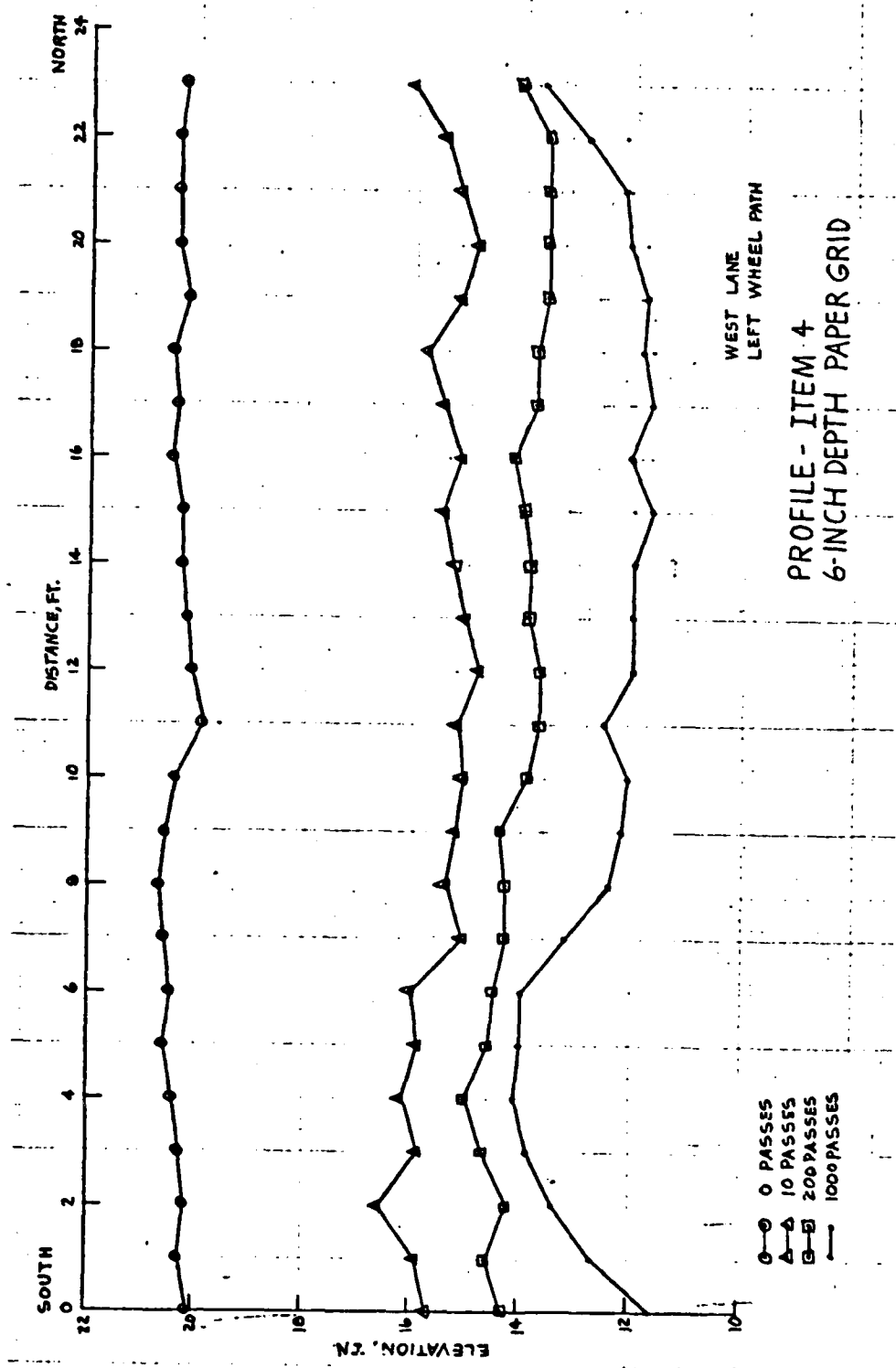
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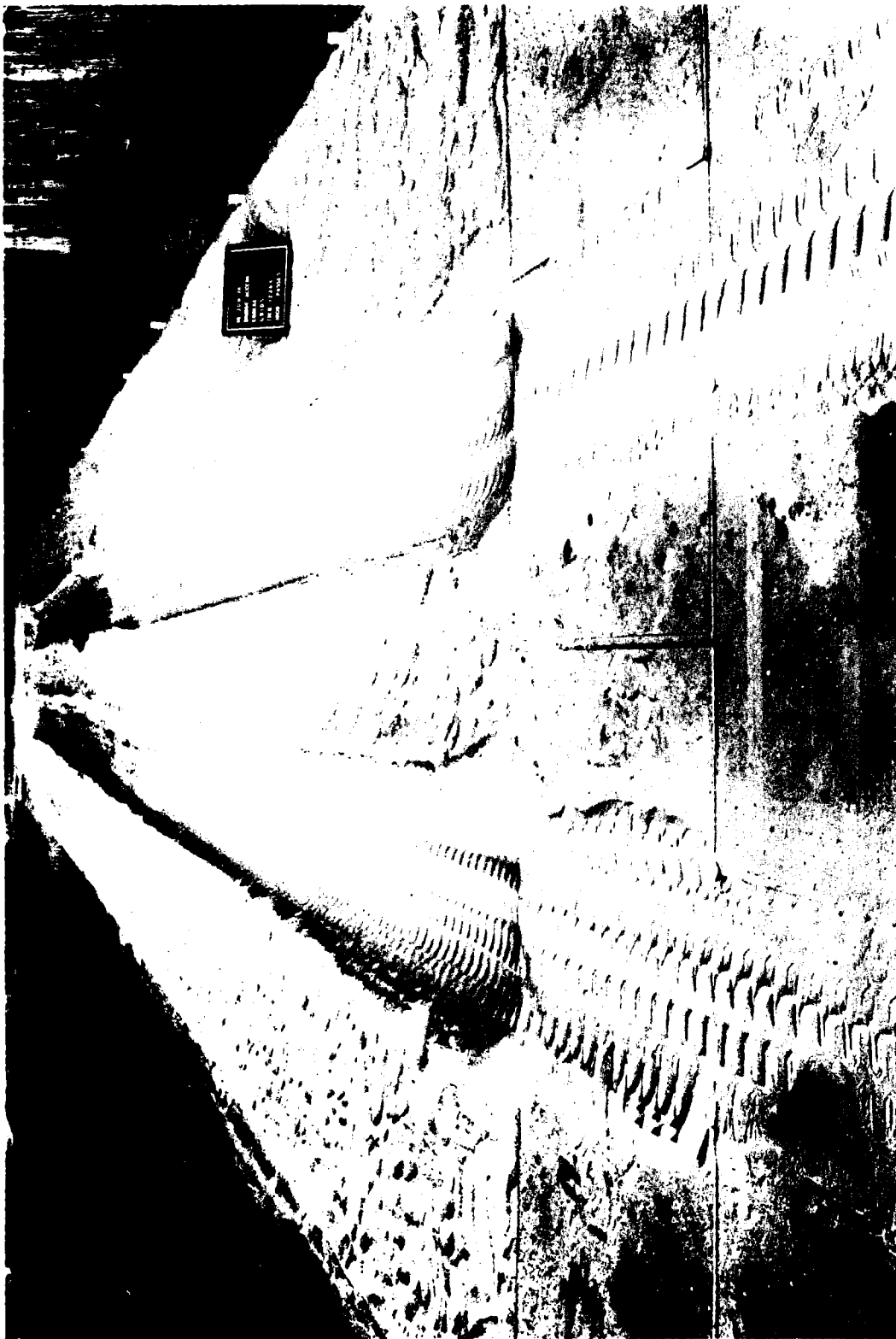
INCL 43 PAGE 1











Test section after 1000 passes of traffic

Incl 45

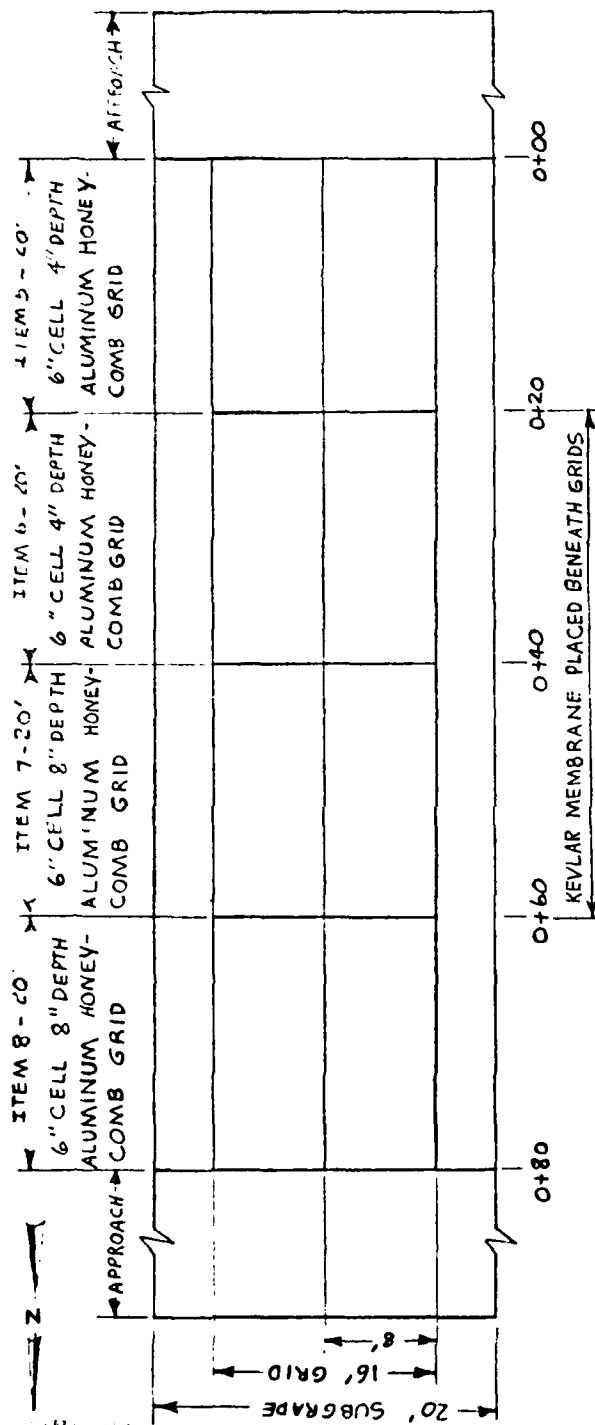
257



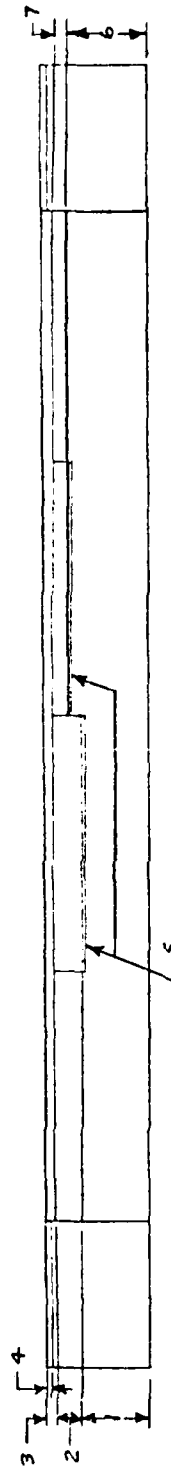
M54 cargo truck on items 1 and 2 after 1000 passes of traffic

Incl 46

258



PLAN



PROFILE

TEST SECTION LAYOUT

6" CELL, 4 AND 8 DEPTH ALUMINUM GRIDS WITH/WITHOUT MEMBRANE



G172-57

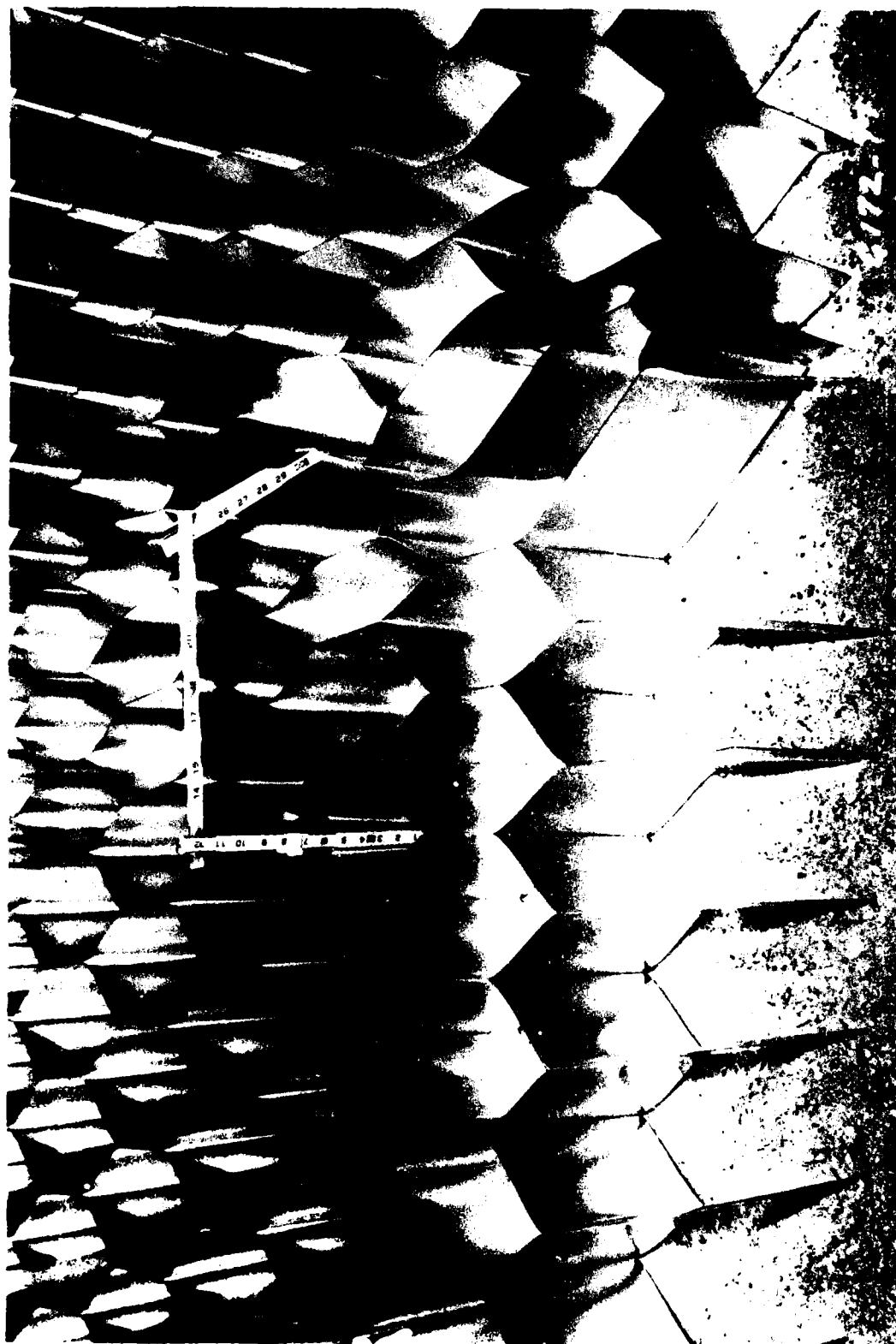
Slabs of 8- and 4-inch depth, 6 inch aluminum cell grid prior to expansion



Close-up of 4-inch depth 6-inch cell aluminum grid

Incl 49

261



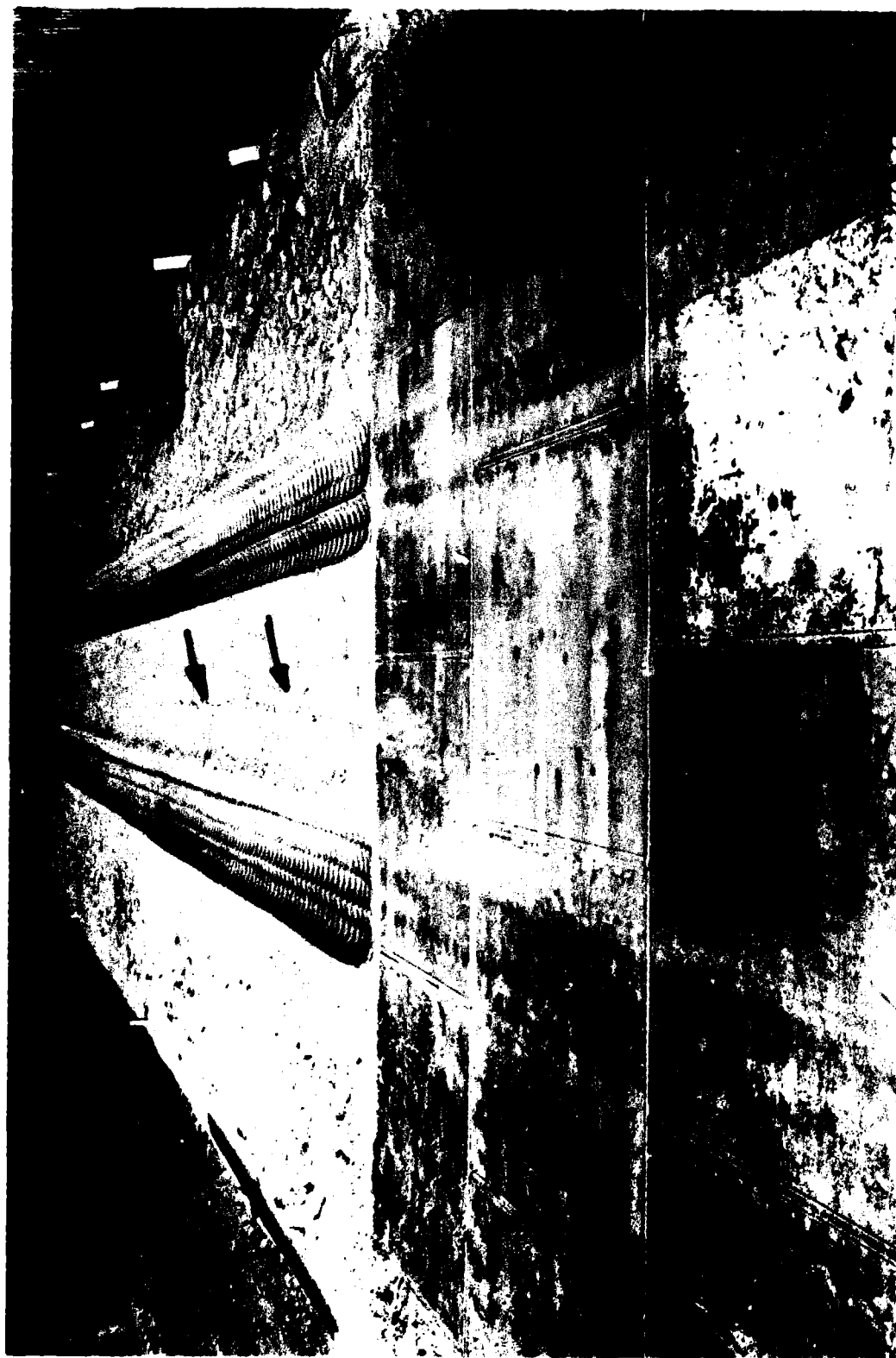
Close-up of 8-inch depth 6-inch cell aluminum grid



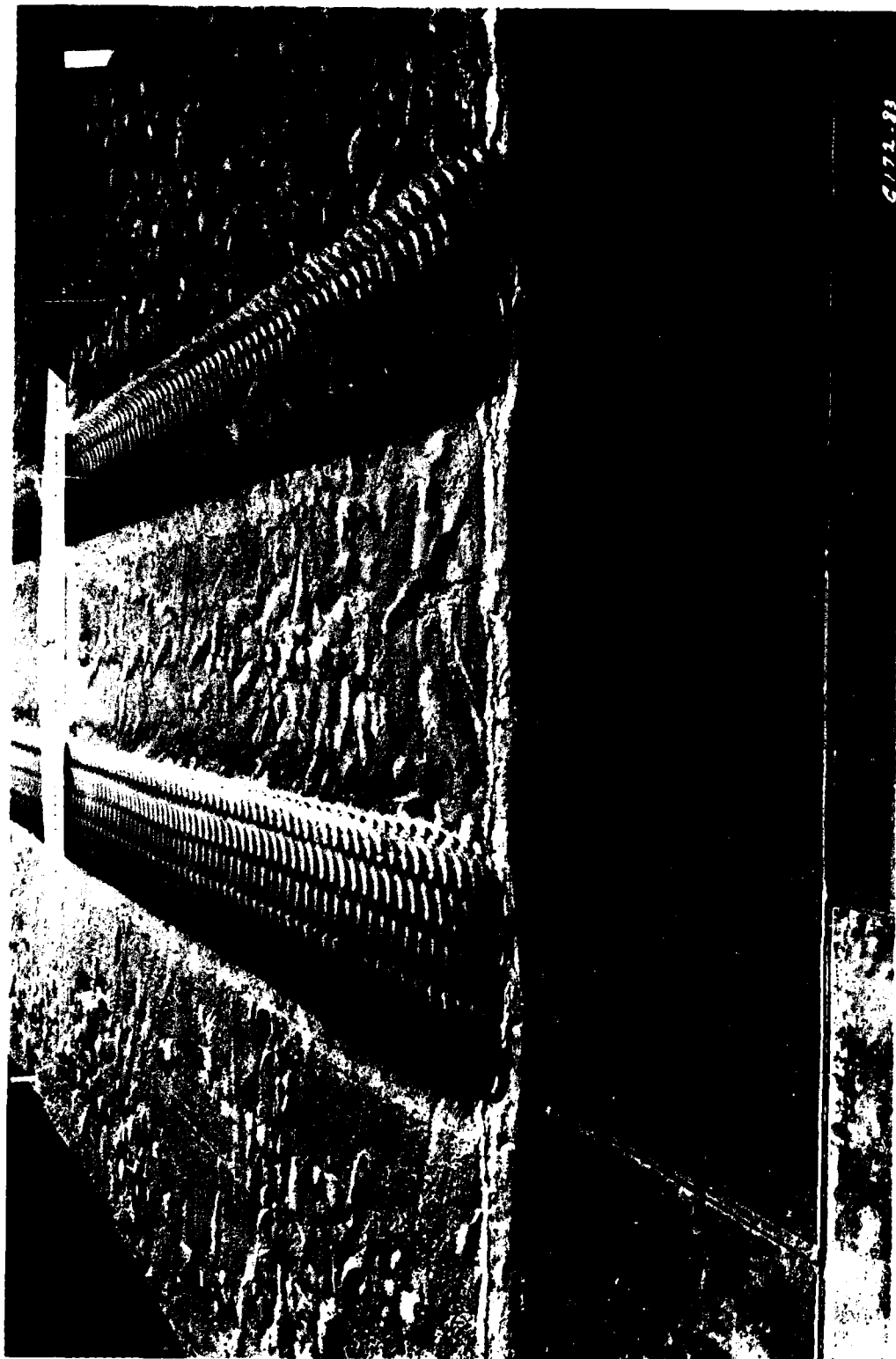
Test section prior to traffic

Incl 51

263



Test section after 10 passes



Q172.83

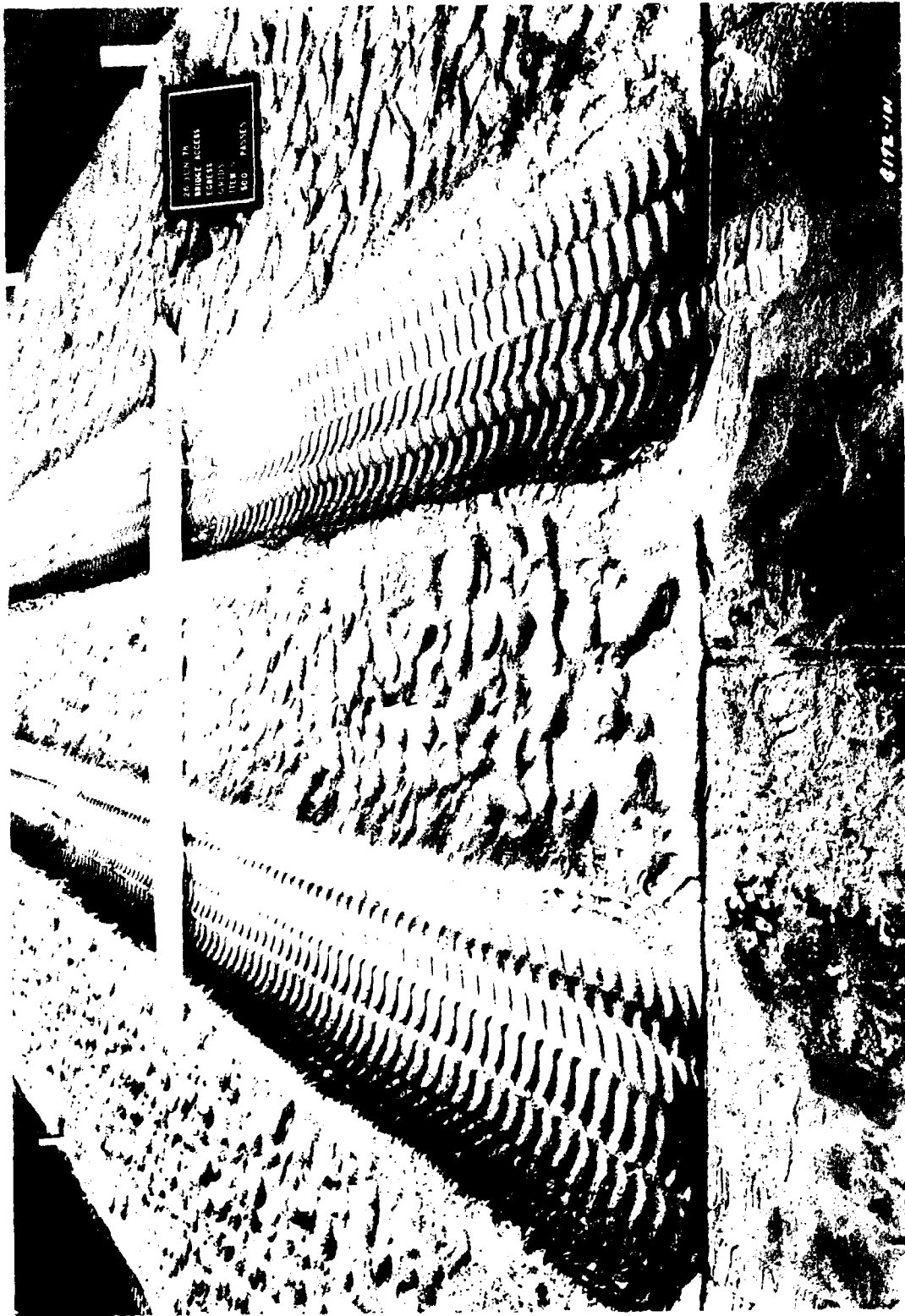
Item 5 after 10 passes

Incl 53

265



Grid in item 5 after 10 passes



Item 5 after 500 passes

Incl 55

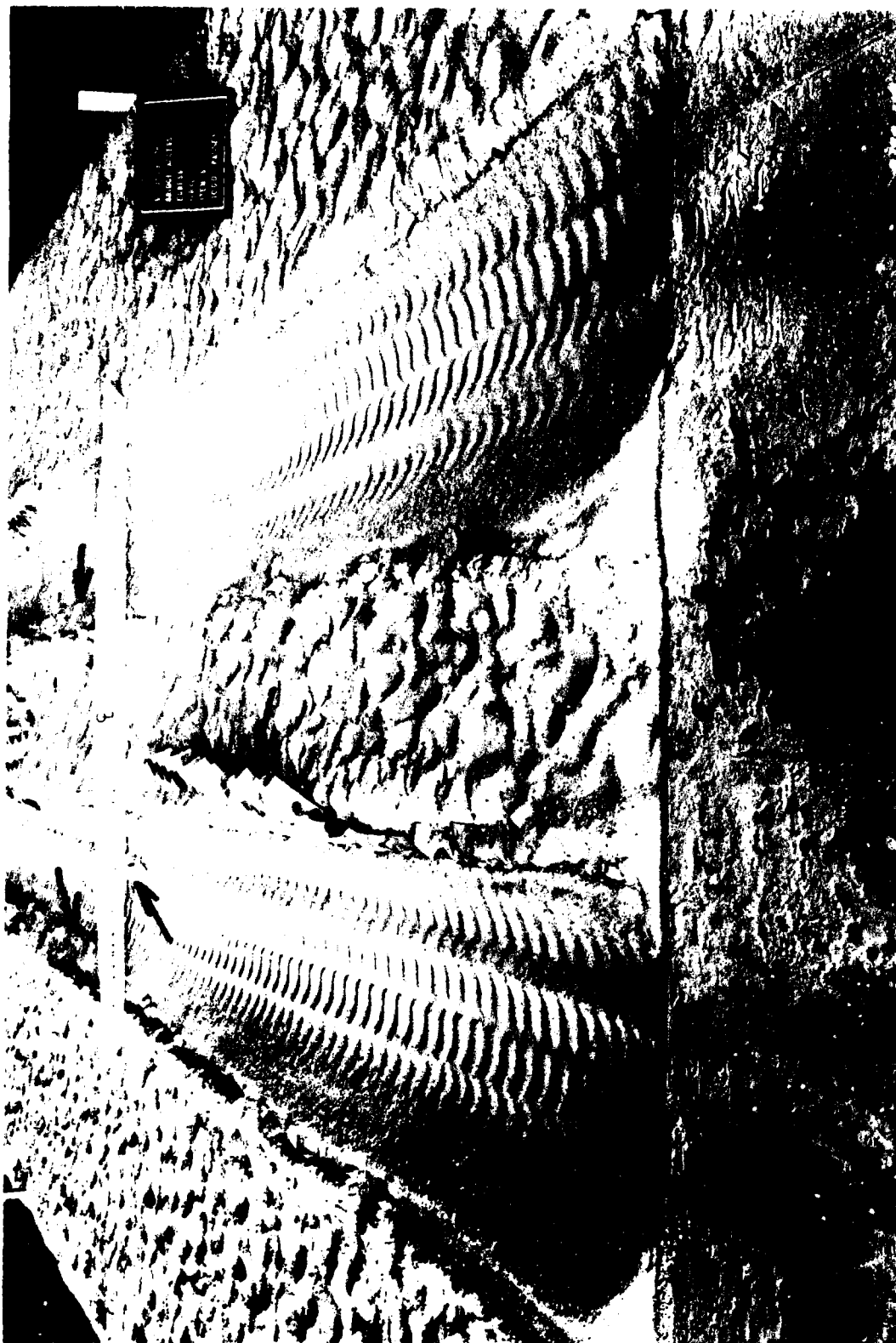
267



Grid in item 5 after 500 passes

Incl 56

268

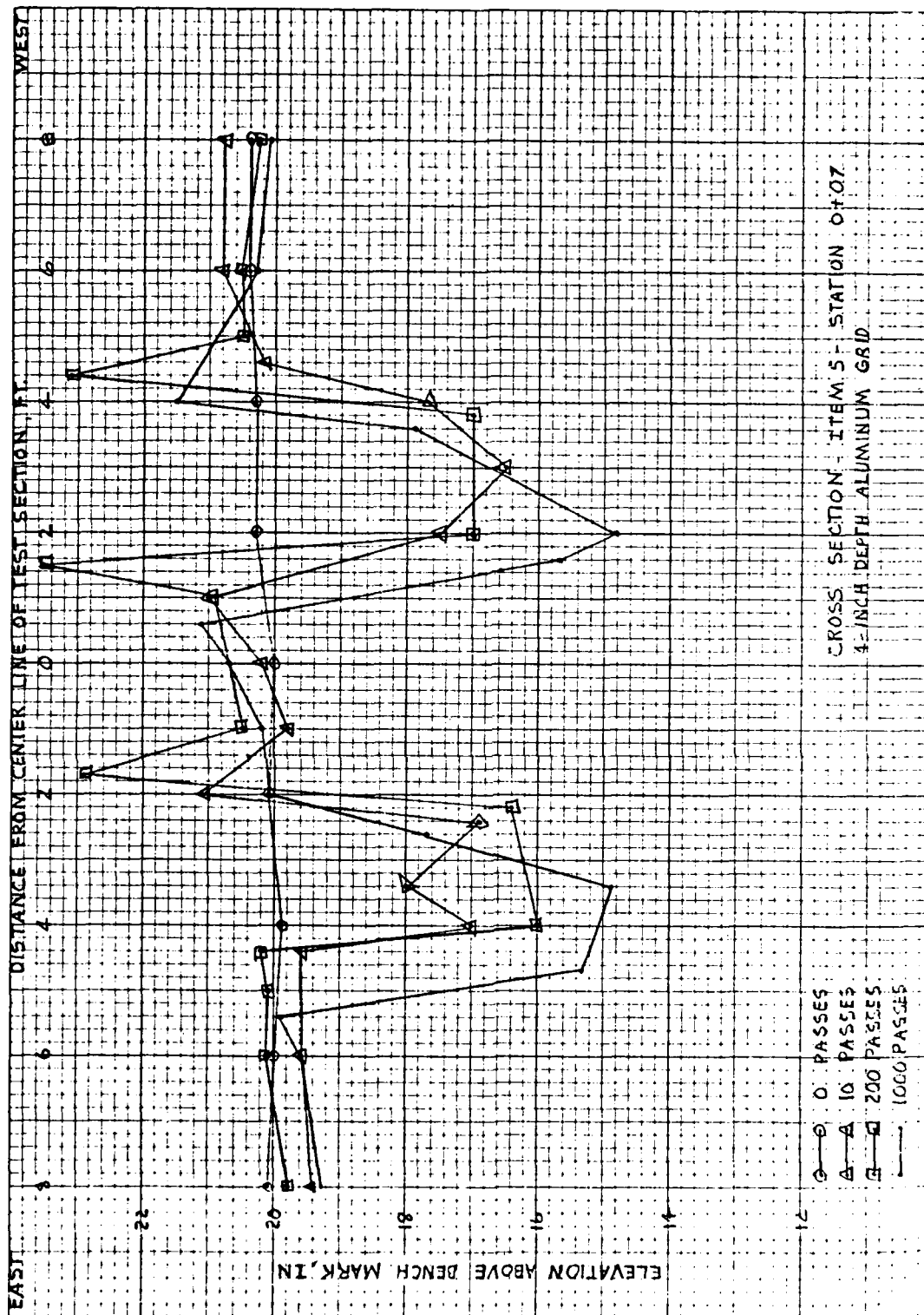


Item 5 after 1000 passes

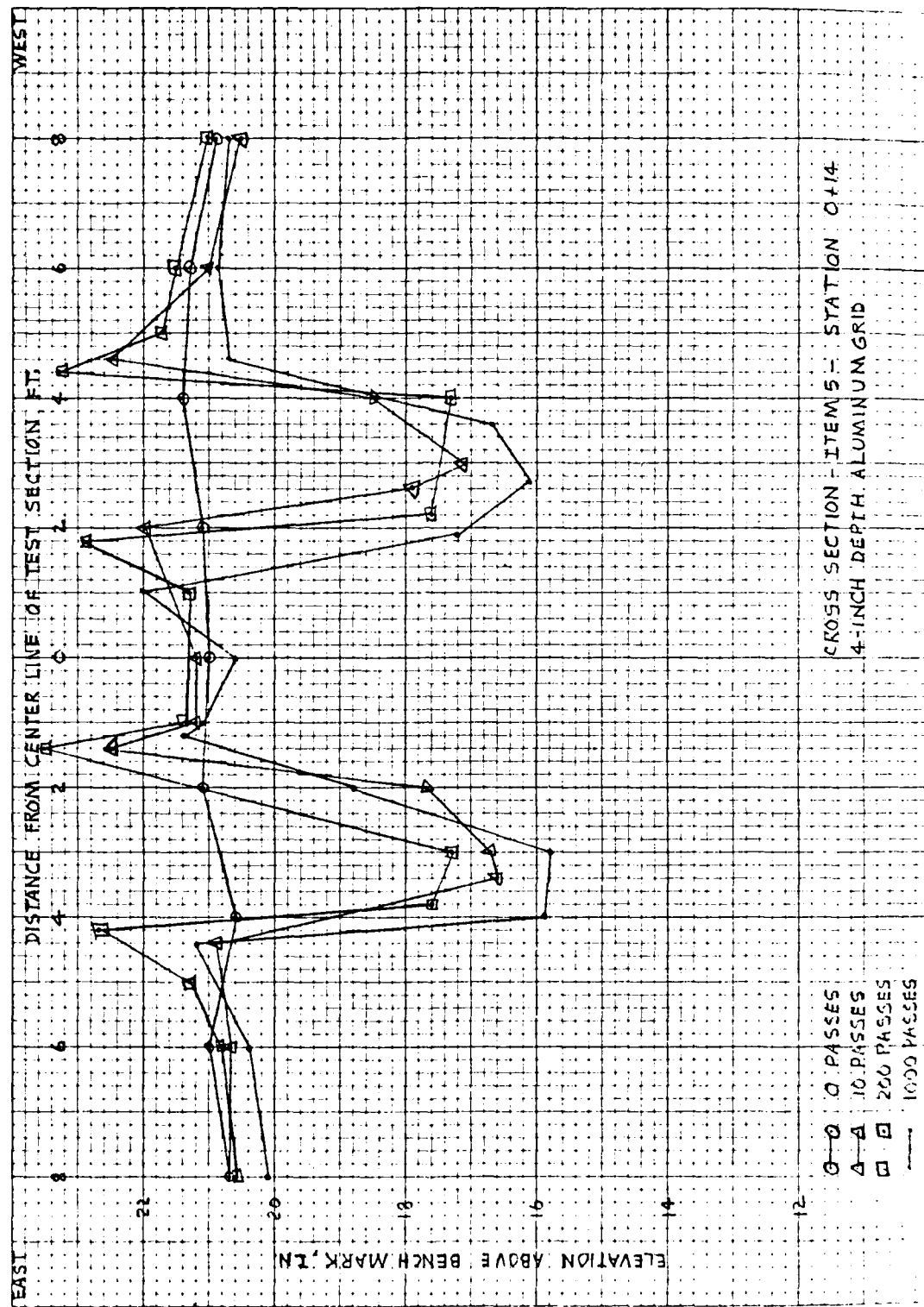
Incl 57

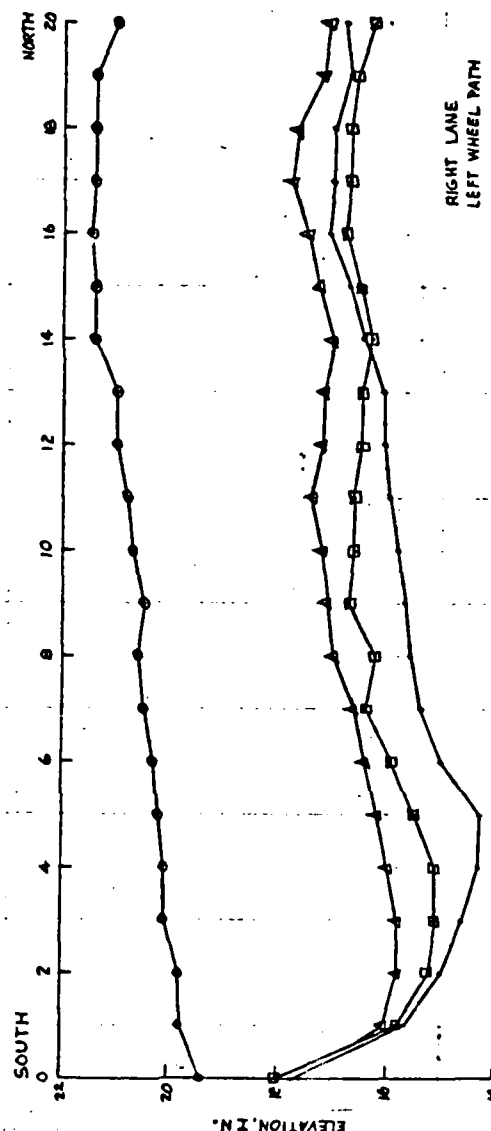
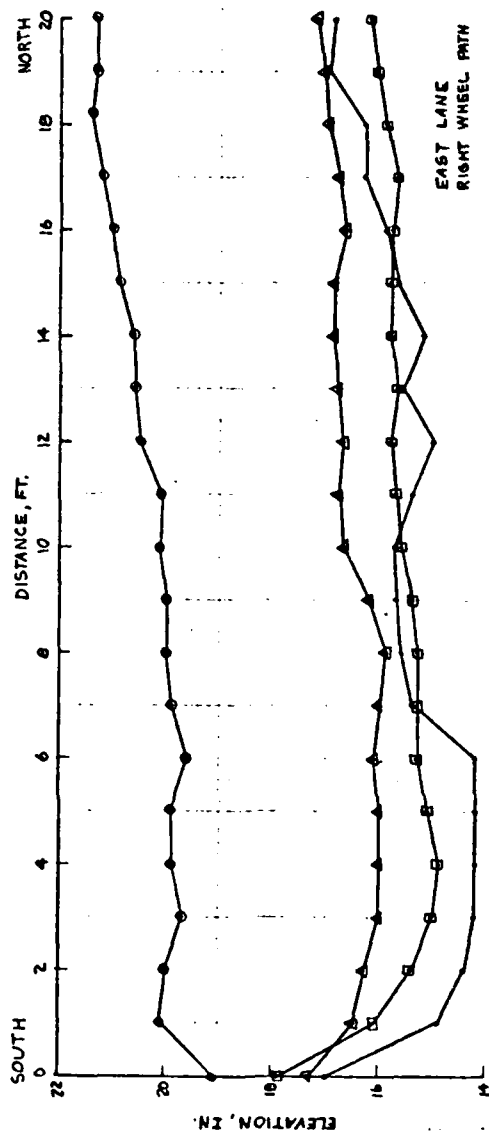
269

INCL 58 PAGE 1



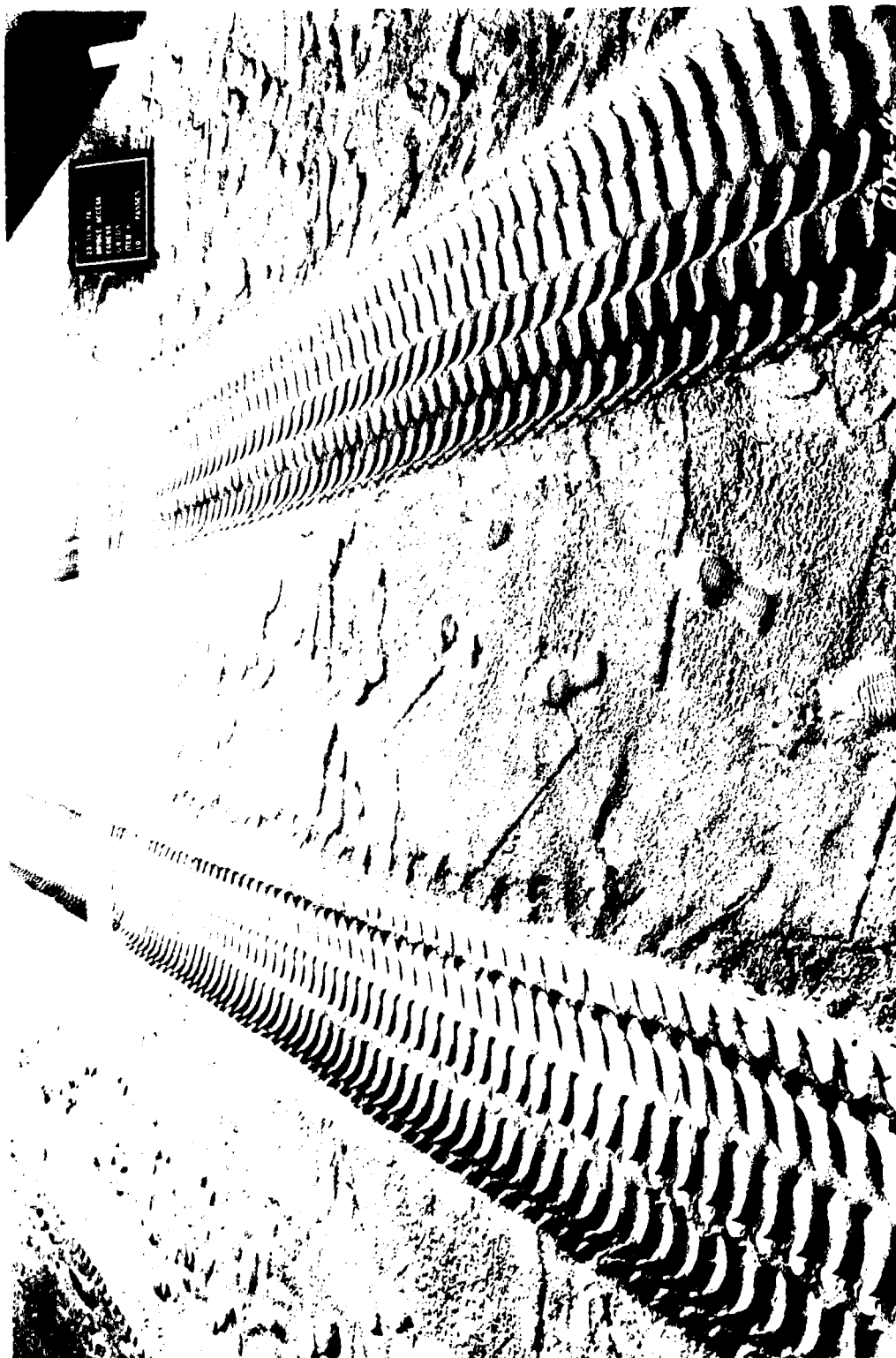
INCL 58 PAGE 2



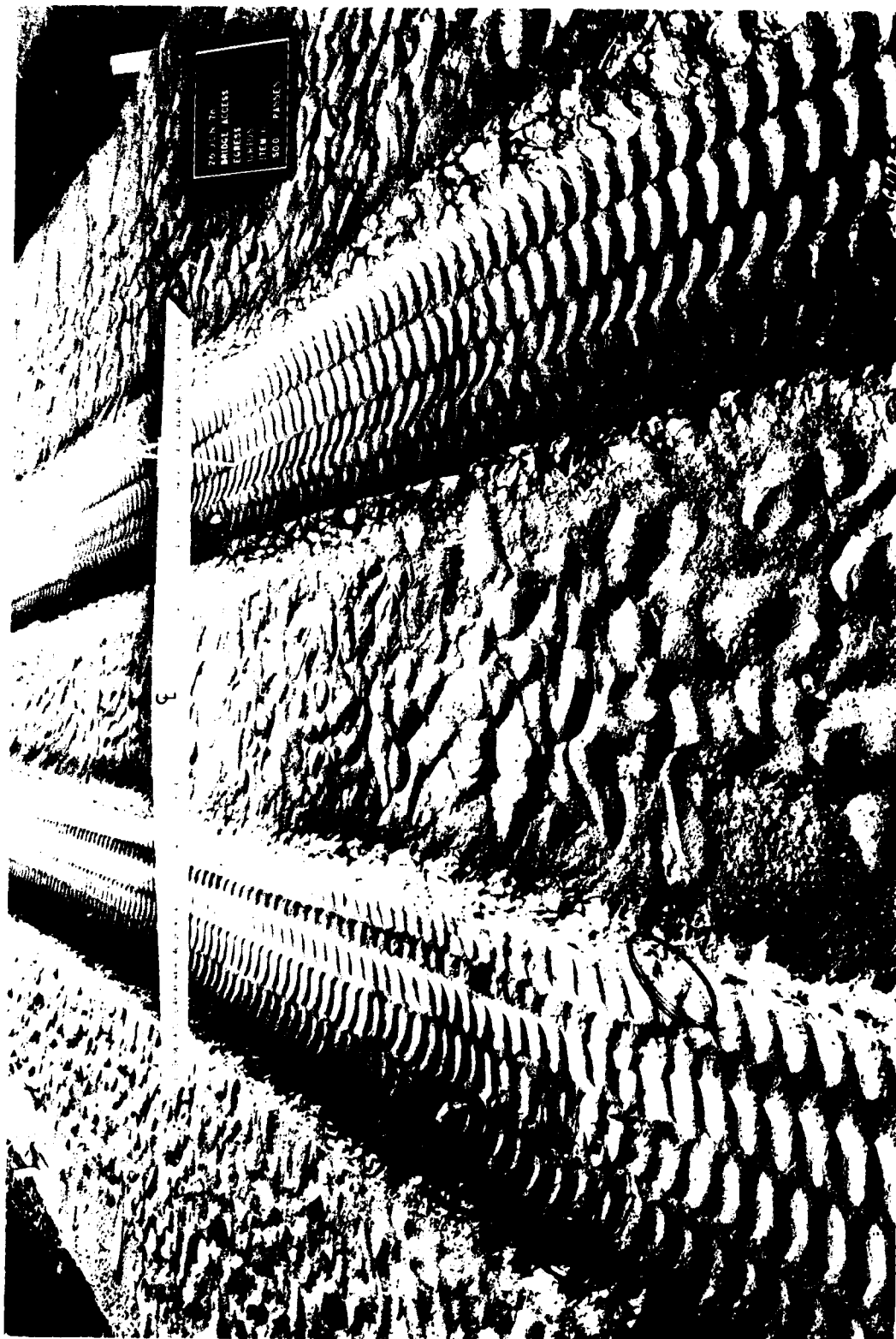


PROFILE- ITEM 5
4-INCH DEPTH ALUMINUM GRID

0 PASSES
10 PASSES
200 PASSES
1000 PASSES



Item 6 after 10 pusses



Item 6 after 500 passes

Incl 61



Grid in Item 6 after 500 passes

Incl 62

275

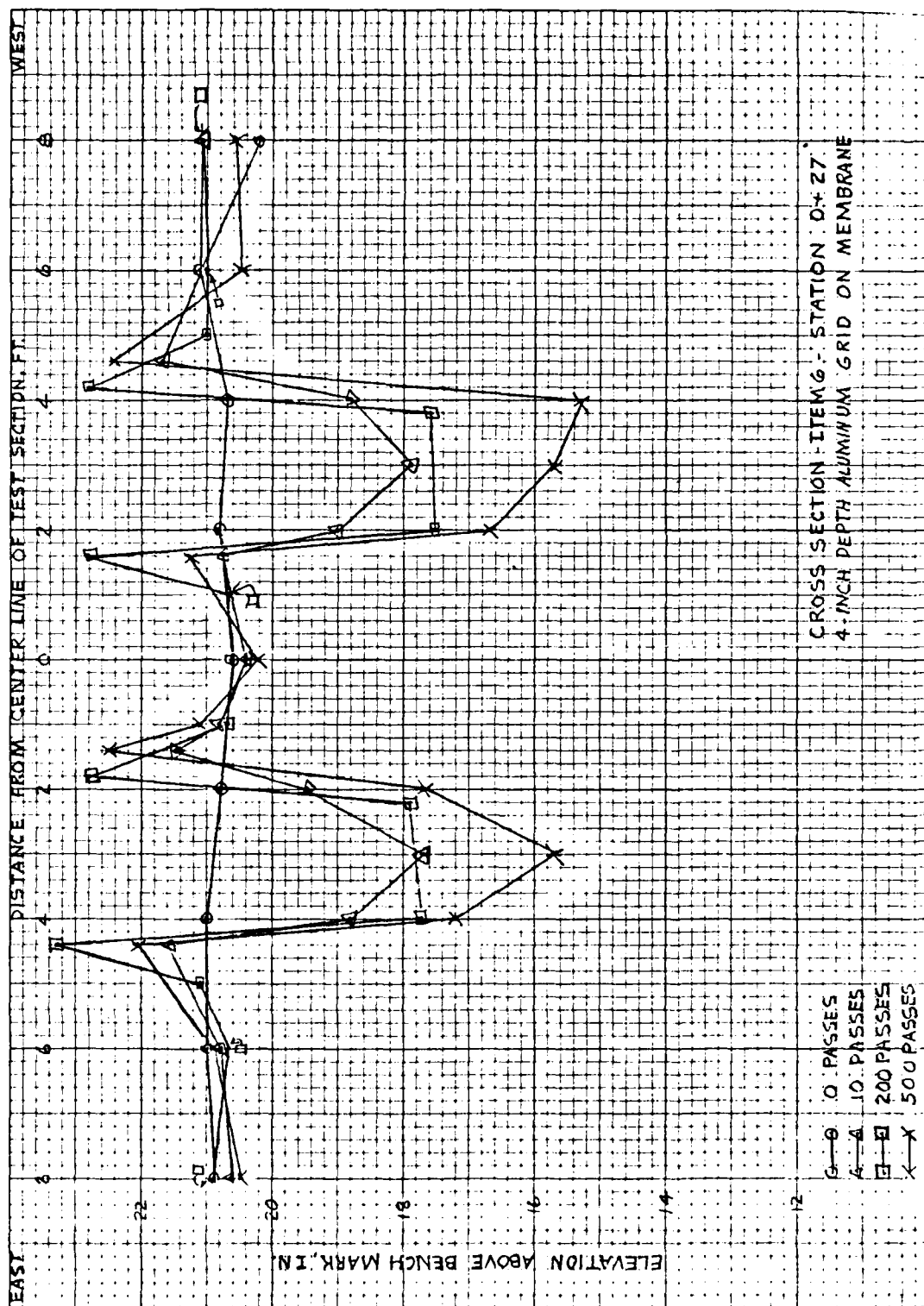


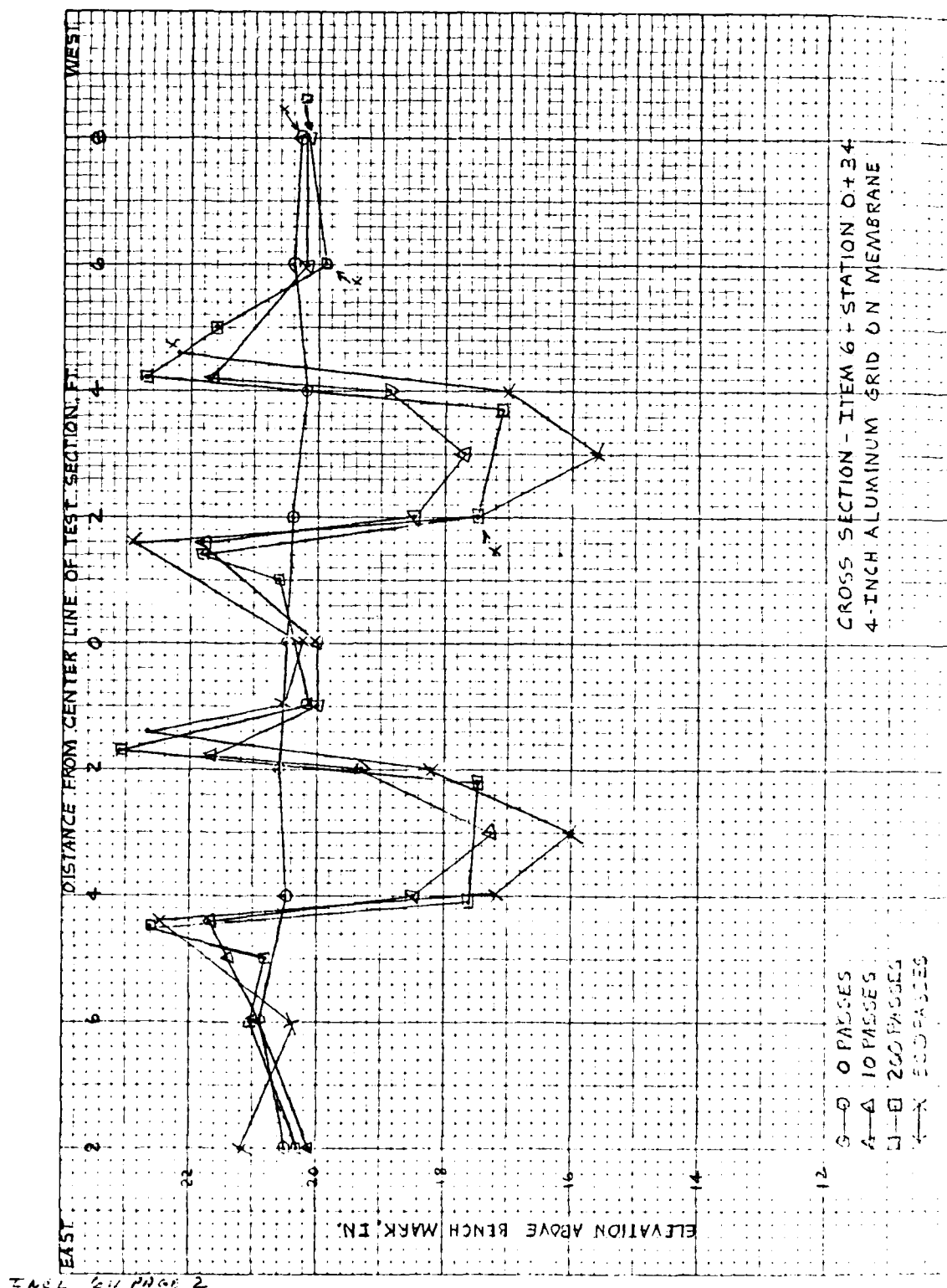
Close up of membrane from Item 6 (4-in.-deep grid)

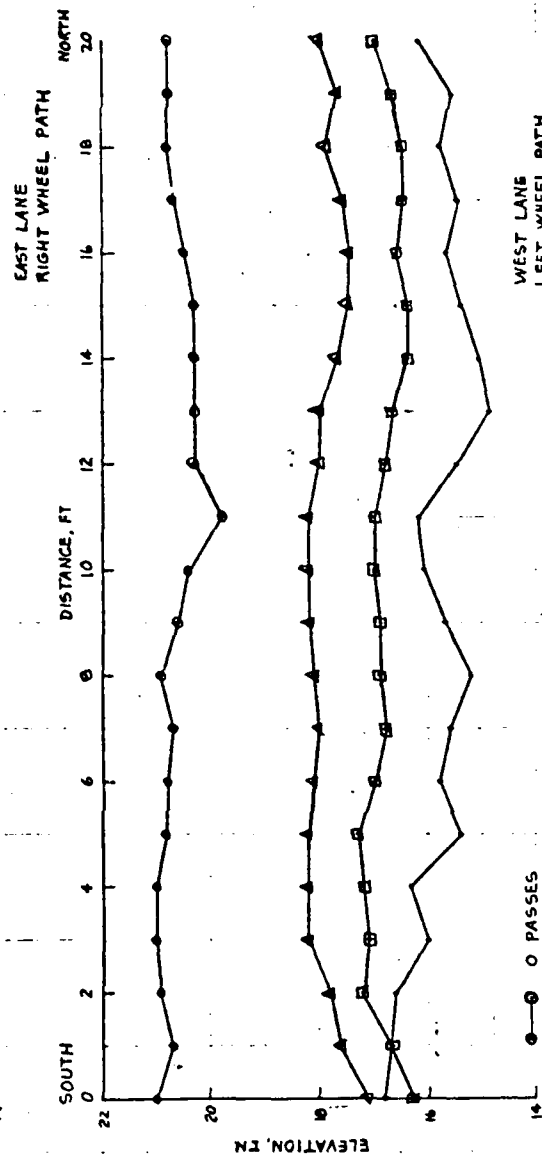
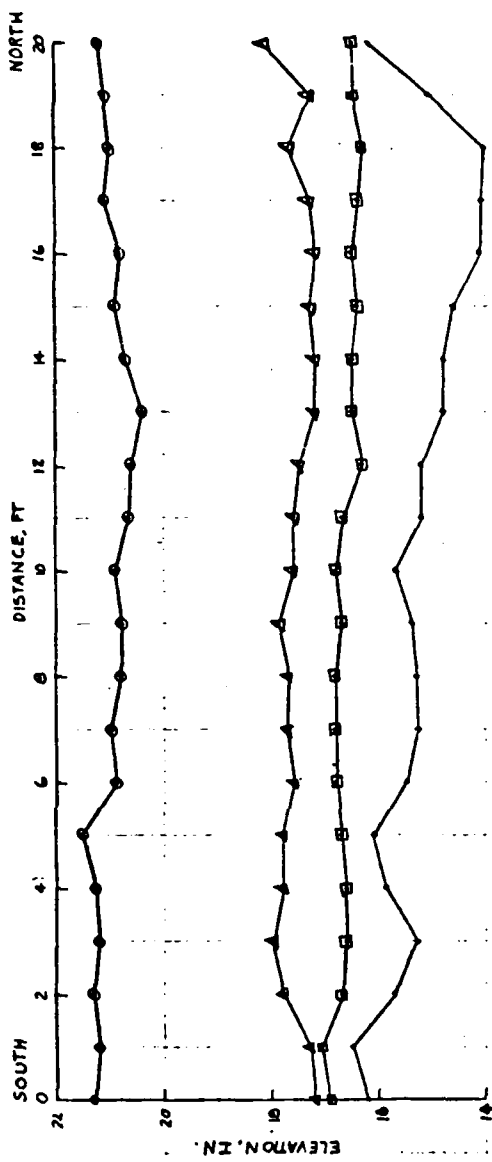
Incl 63

276

INCL 64 PAGE 1

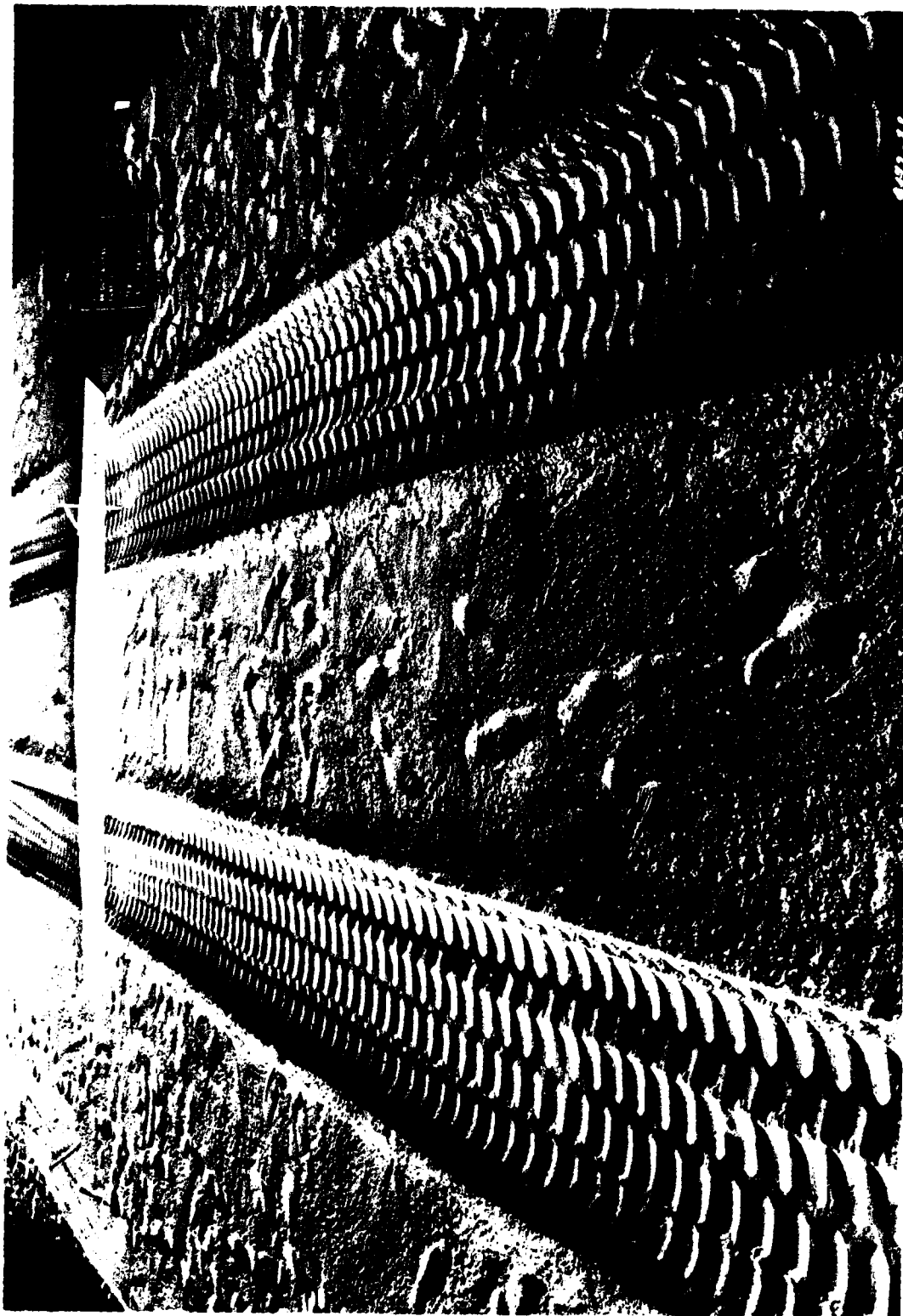




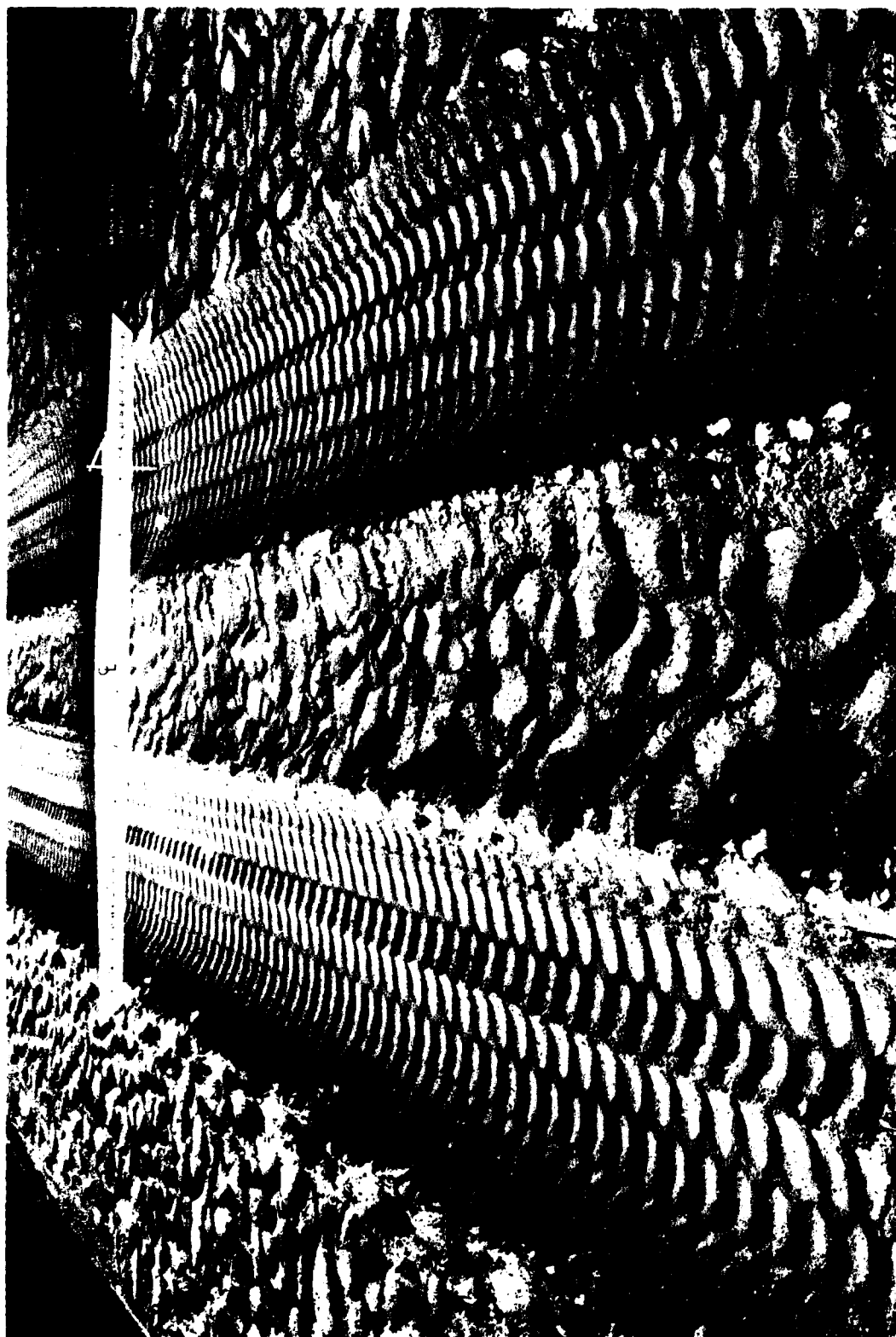


PROFILE - ITEM 6
4-INCH ALUMINUM GRID ON MEMBRANE

FIGURE 6



Item 7 after 10 passes



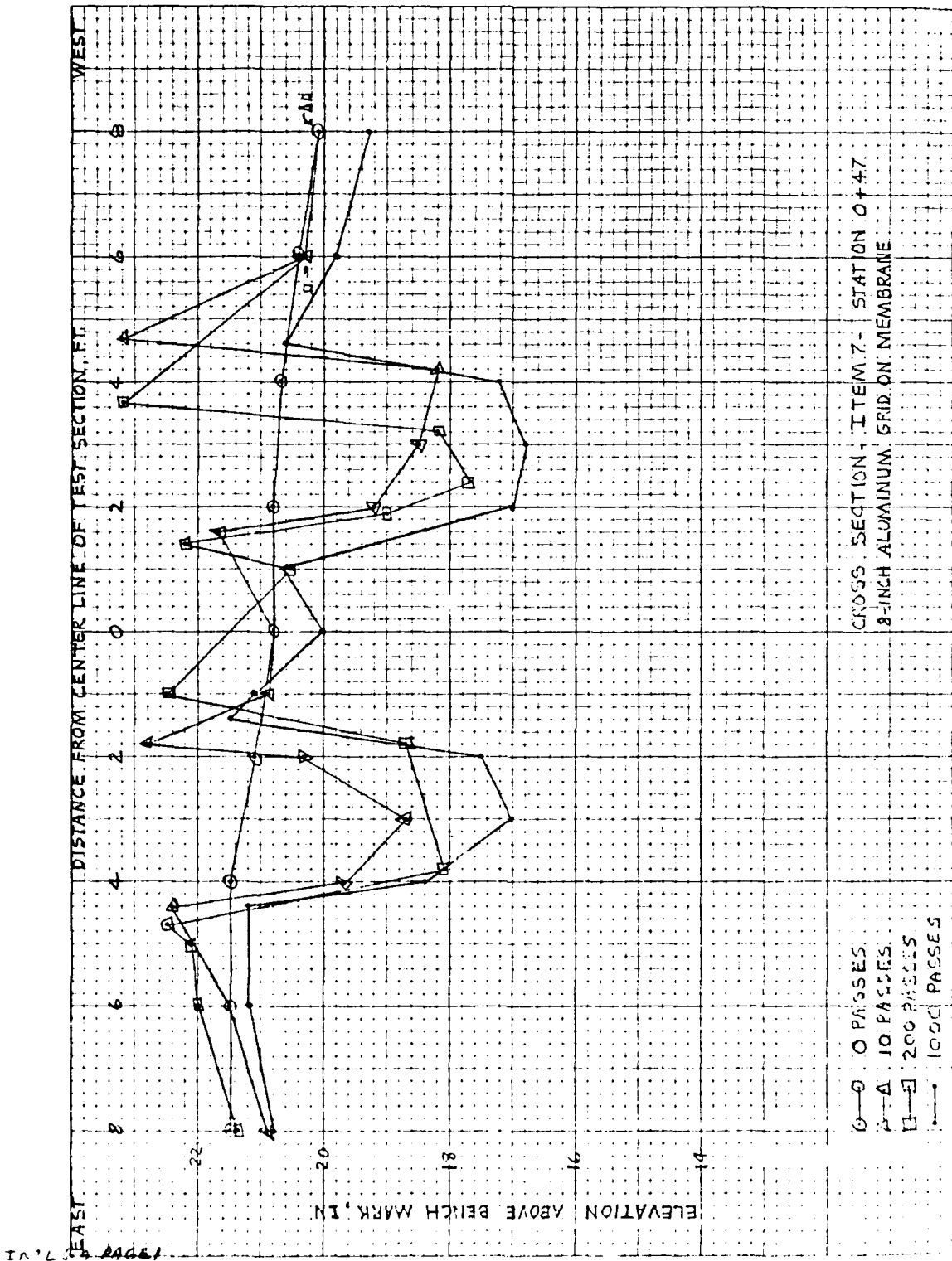
Item 7 after 1000 passes

Incl 61

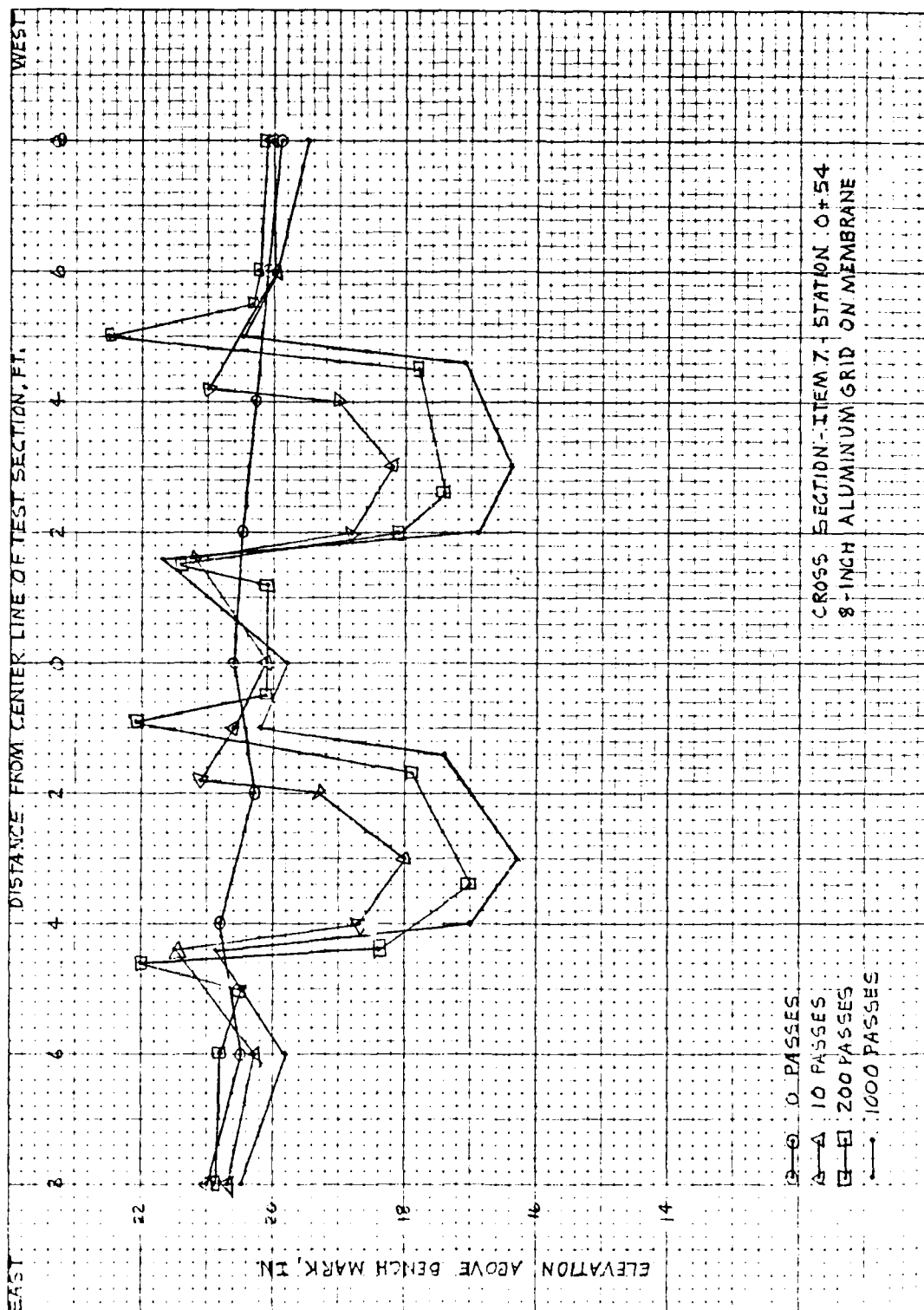
281

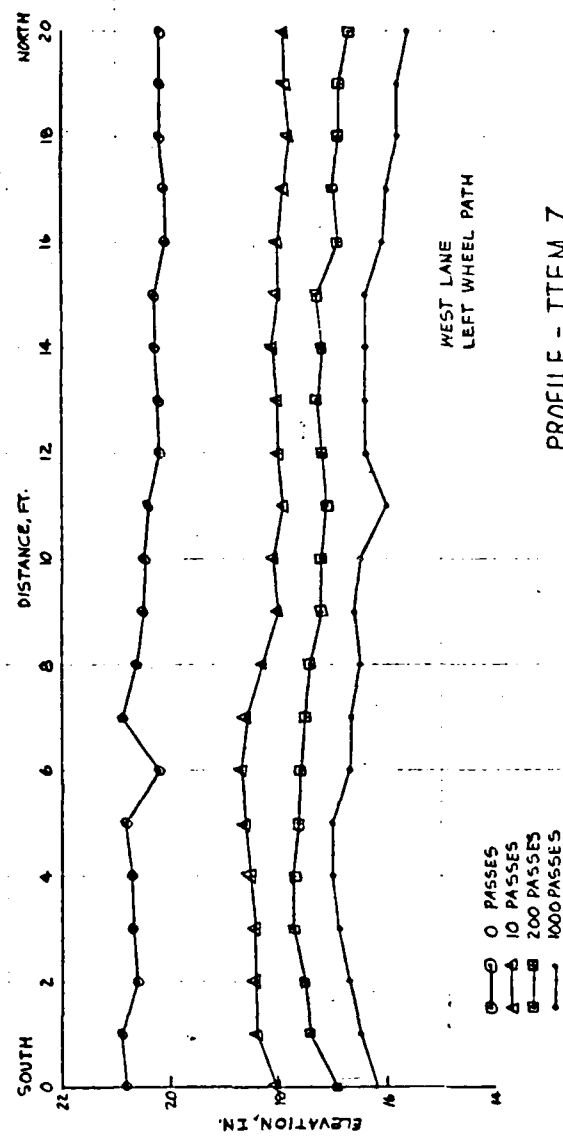
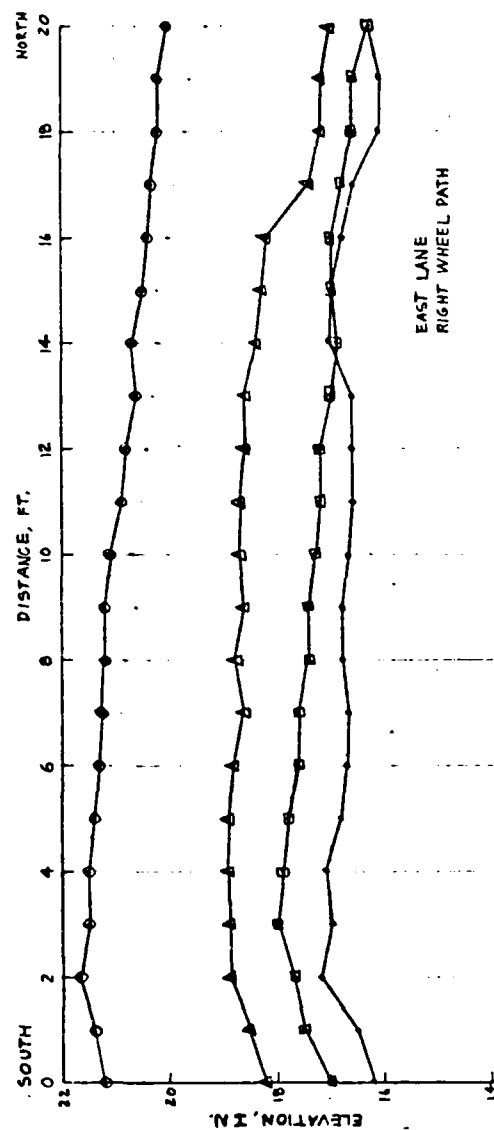


Grid in item 7 after 1000 passes

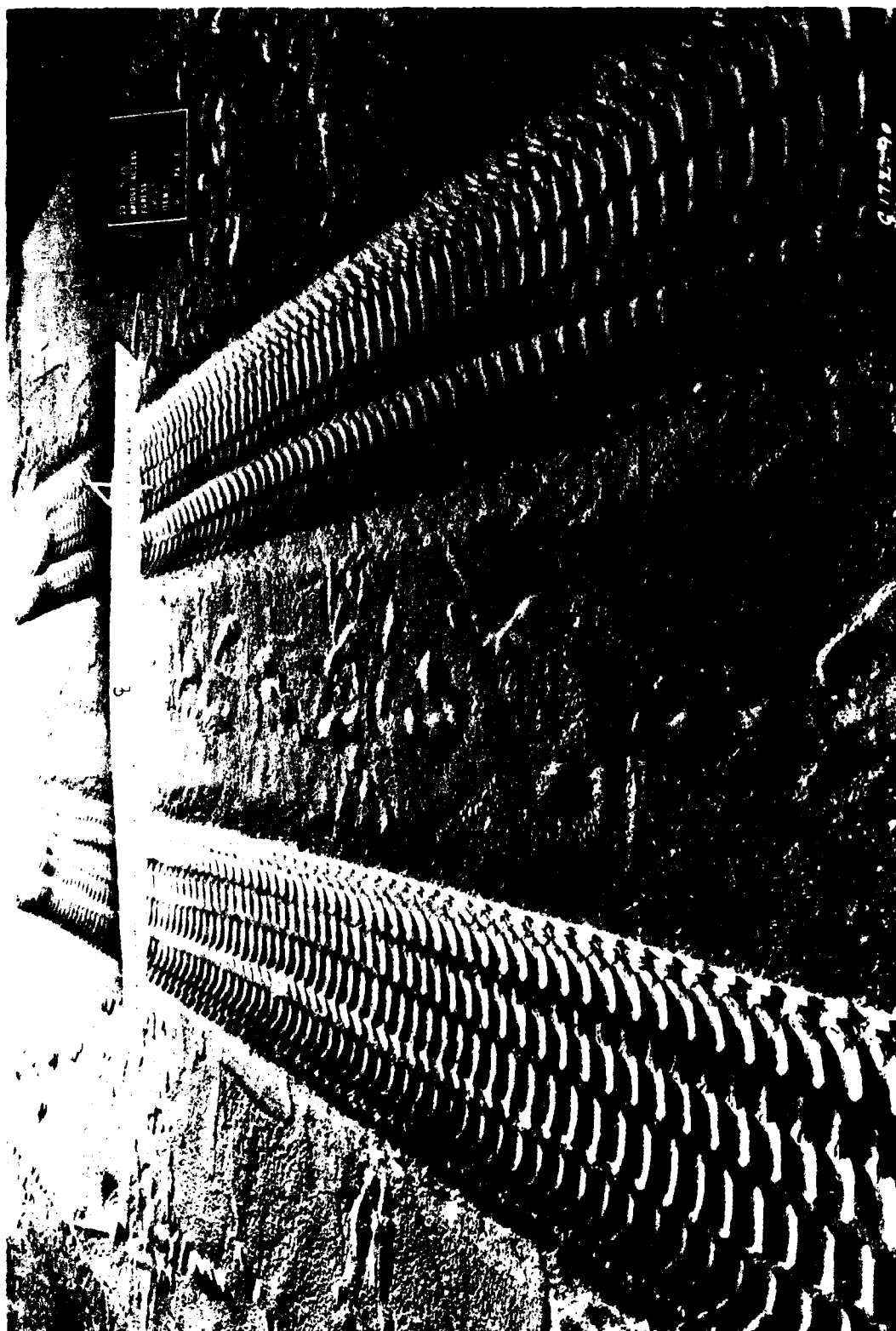


INCL 64 1952





PROFILE - ITEM 7
8-INCH ALUMINUM GRID ON MEMBRANE



Item 8 after 10 passes

Incl 71

286

AD-A139 488

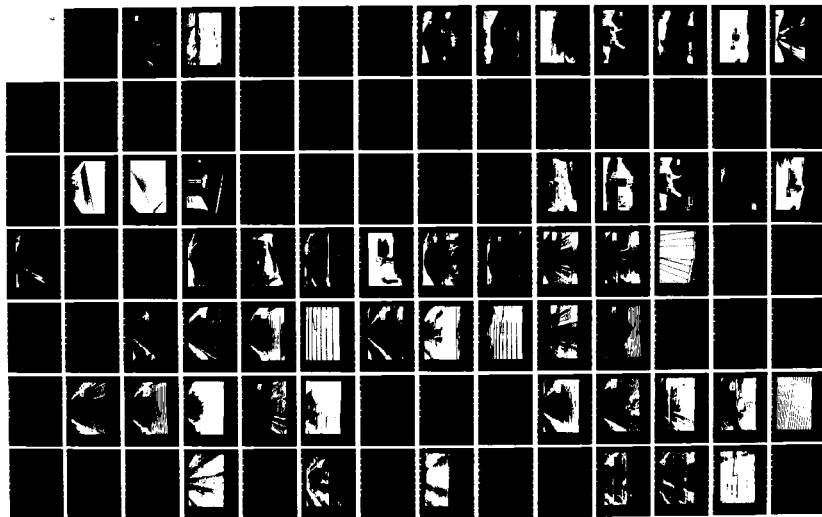
TACTICAL BRIDGE ACCESS//GRESS PRELIMINARY
INVESTIGATIONS(U) ARMY ENGINEER WATERWAYS EXPERIMENT
STATION VICKSBURG MS GEOTECHNICAL LAB B A NATIS SEP 80

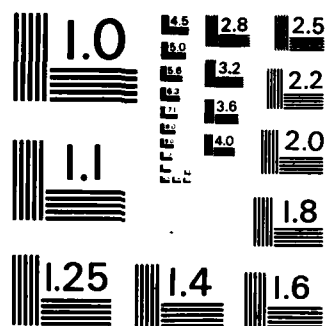
4/6

UNCLASSIFIED

F/G 13/2

NL

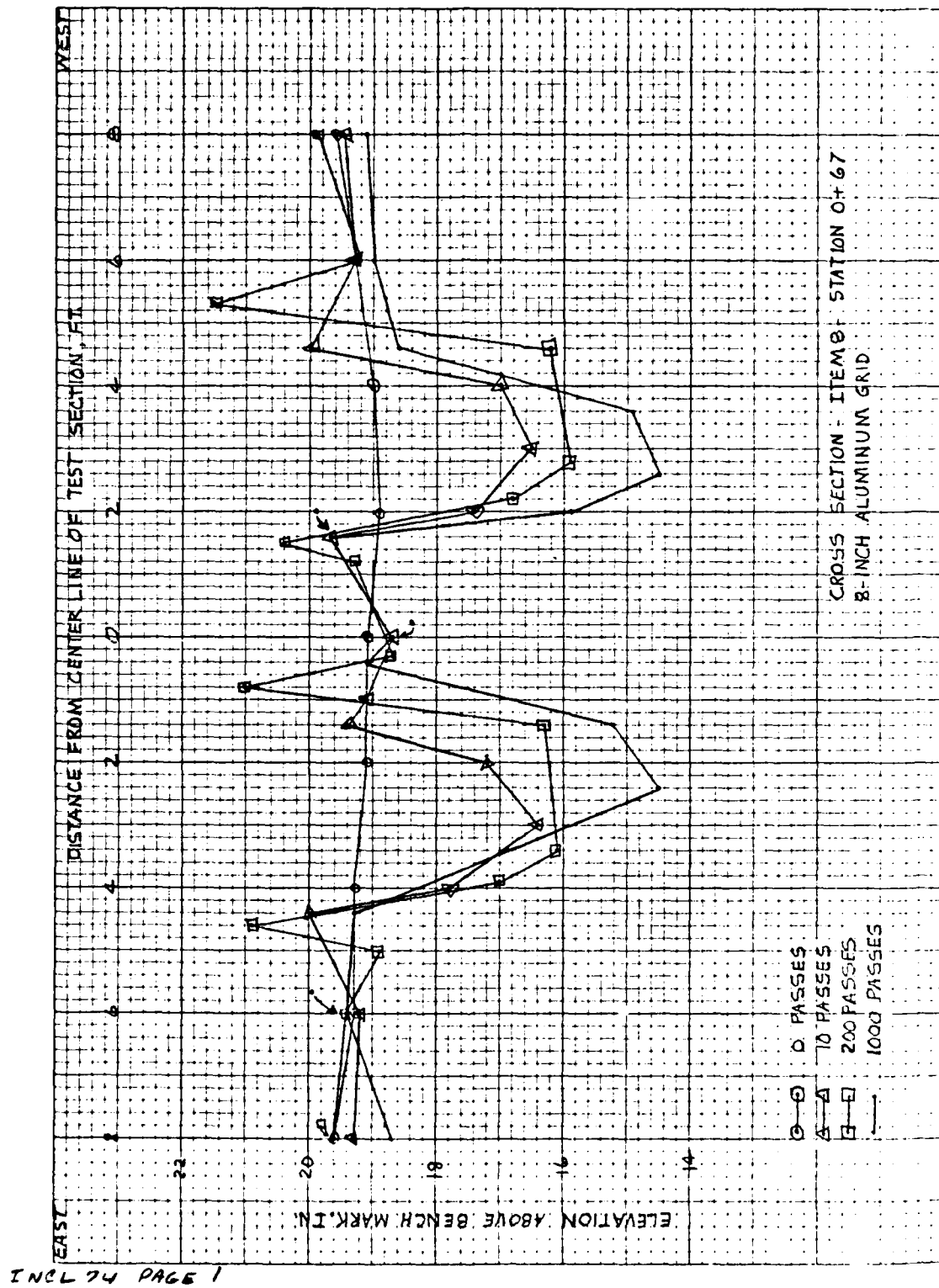




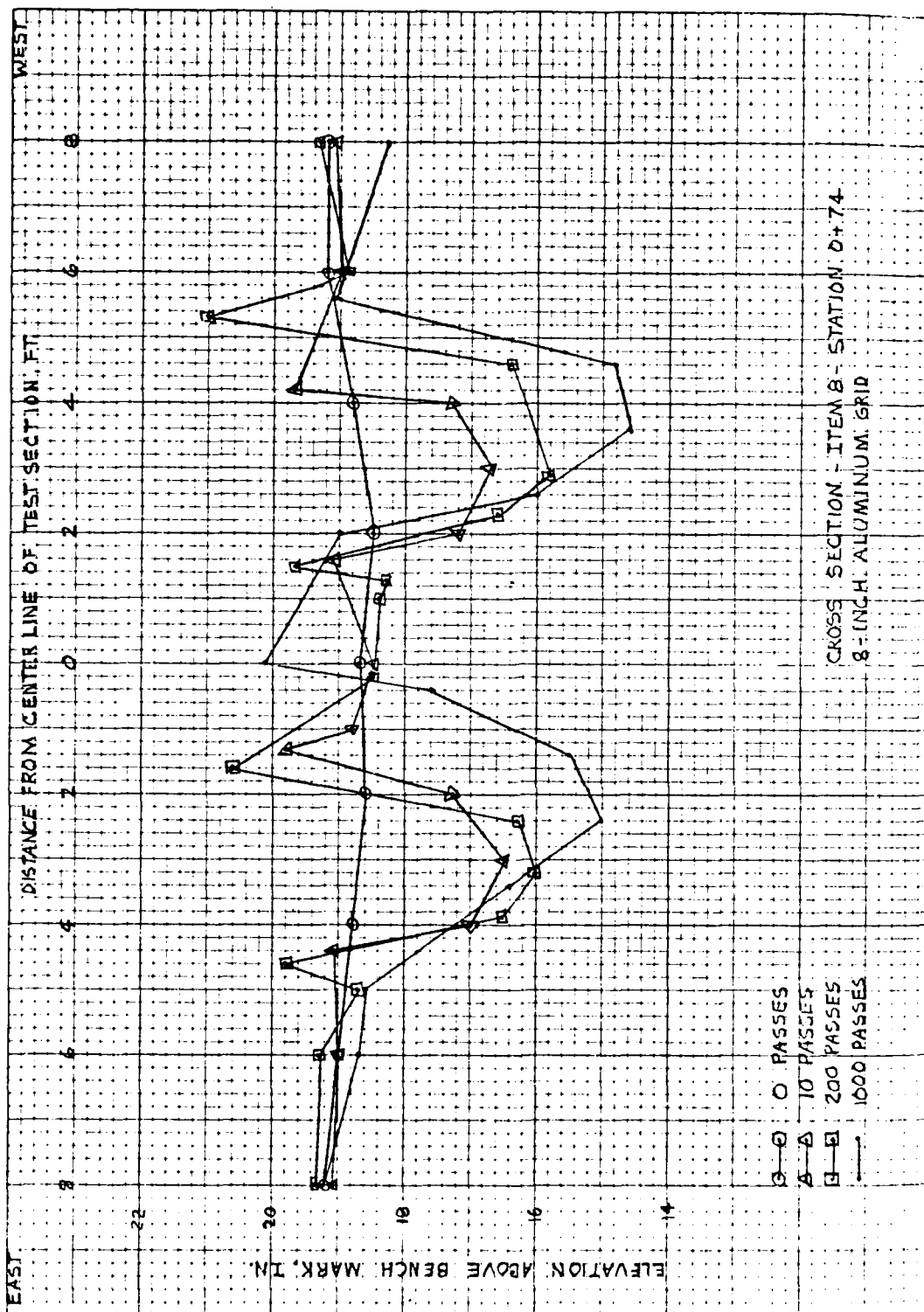
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

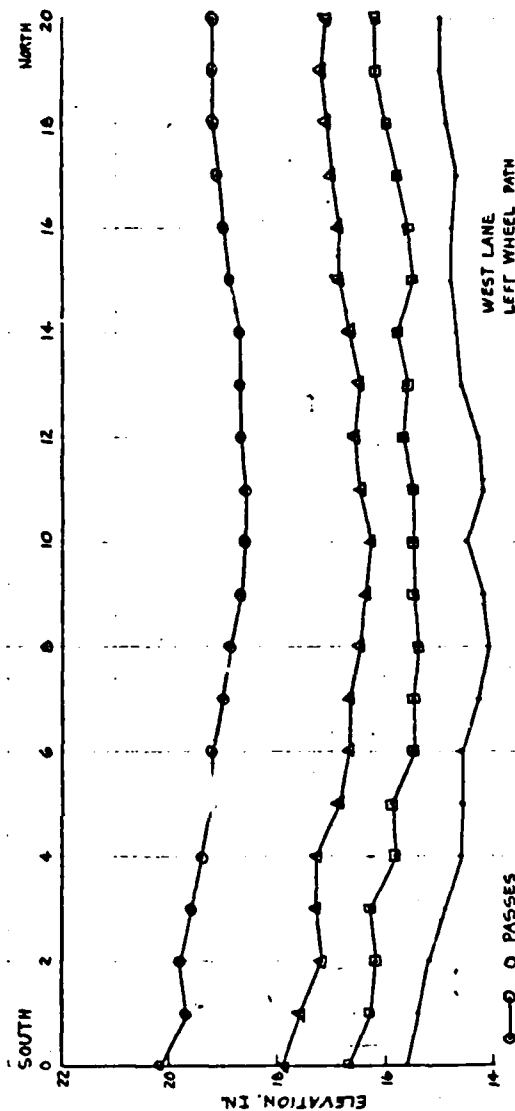
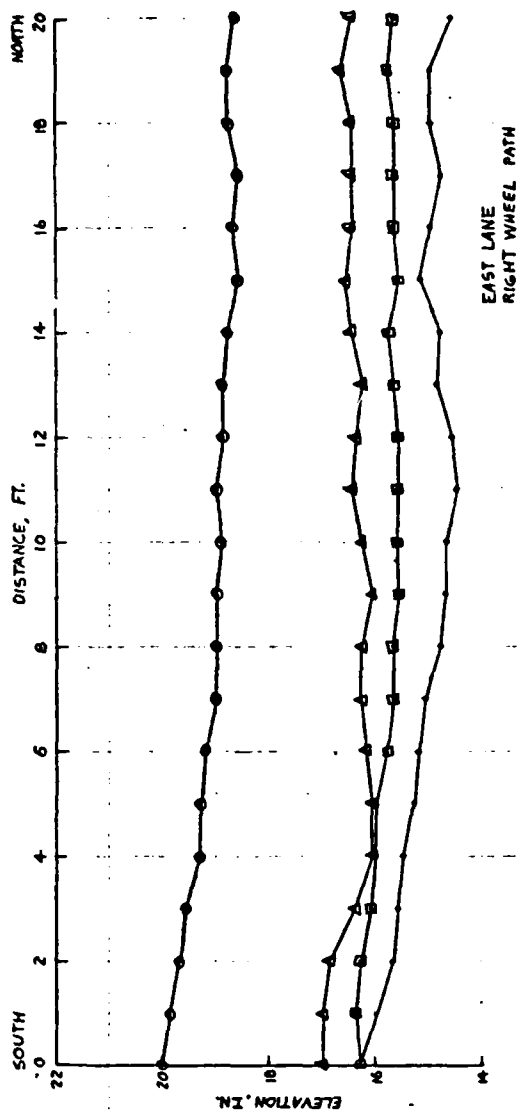


Grid in item 8 after 1000 passes



INCL 74 PAGE 2





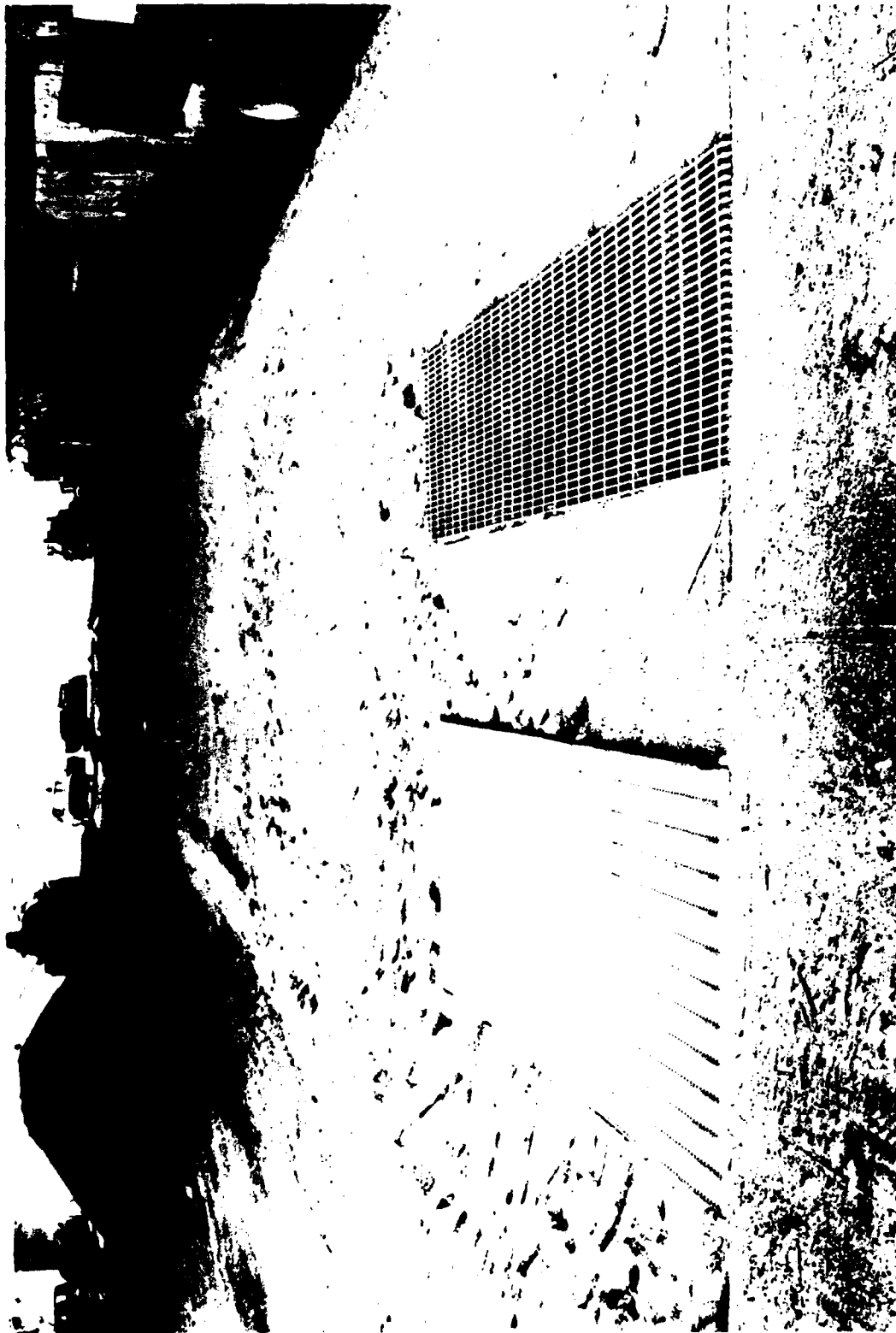
PROFILE- ITEM 8
8-INCH ALUMINUM GRID

PREPARED BY: R. J. JONES, JR.



Test section after 1000 passes

Incl 7c



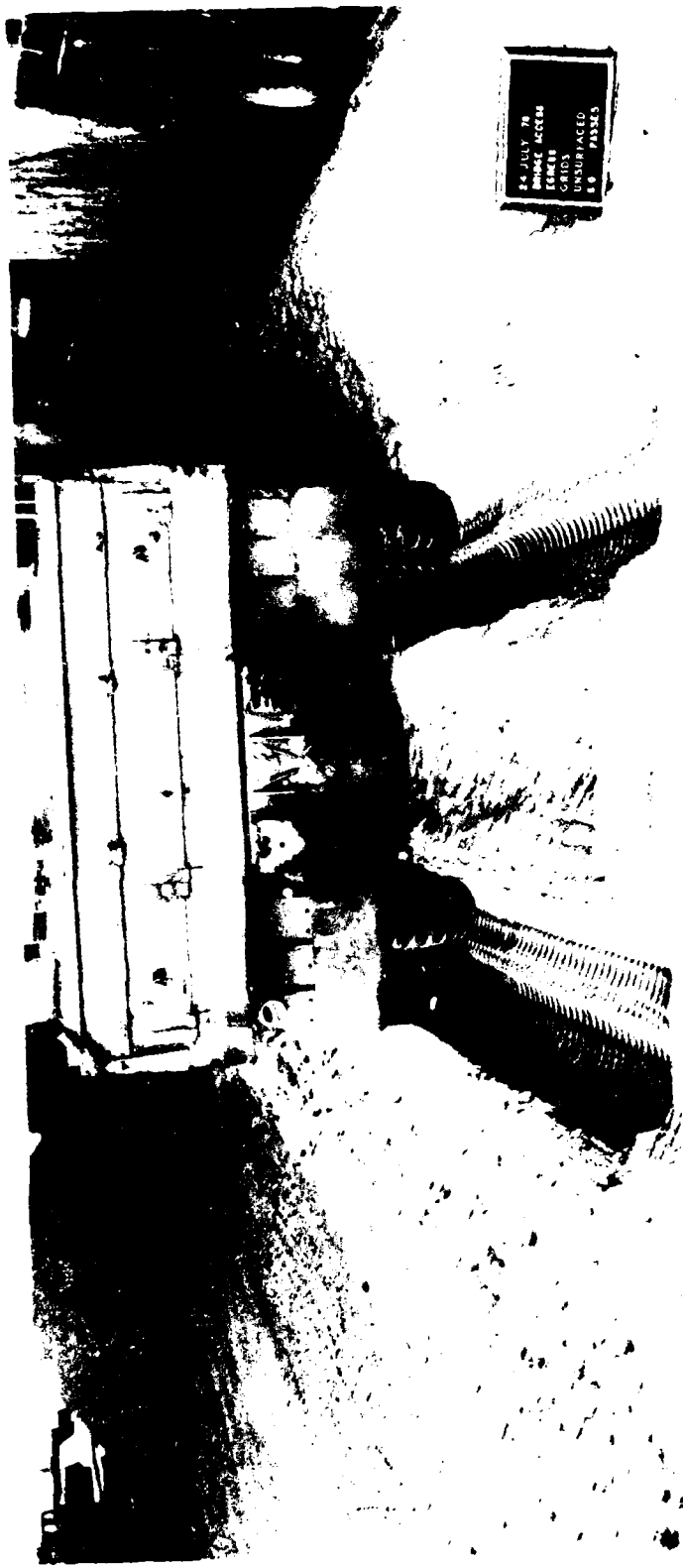
Test section for M54 truck (20,000 lb) traffic



Test section after two passes of M54 truck (20,000 lb)

Incl 78

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24 JULY 78
BRIDGE ACROSS
RIVER
STATION
UNSUBSIDIZED
10 PMS/5

Test section after 50 passes of M5A truck (20,000 lb)



Test section for M54 truck (40,000 lb) traffic

Incl 80

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M54 truck (40,000 lb) immobilized in loose sand test section

Incl 81



Sand subgrade after M54 cargo truck (40,000 lb) removed

Summary of Land Confinement Investigation

Materials	Grid Size	Grid Depth	Weight	Panel Size	Cost	With/Without Membrane	Number of Passes	Rut Depth, in.	Comments
None	-	-	-	-	-	W/O	0*	>12	Truck became immobilized after going about 20 ft in loose sand.
None	-	-	-	-	-	W/O	10	7-8	Truck undercarriage touched sand subgrade after 50 passes.
Paper Honeycomb	6 in.	6 in.	57 lb 0.29 lb/sq ft	2-15/16 in. X 10 ft 8 in.	\$0.61/ sq ft	W/O W	10 10 10 200 200	11-12 7.4 6.8 9.0 10.8	Paper grid after 200 passes had lost all usefulness in confining the sand.
Aluminum Honeycomb	6 in.	4 in.	55 lb 0.34 lb/sq ft	1-5/16 in. X 10 ft 1-1/2 in.	\$1.38/ sq ft	W/O W W W/O	10 500 500 1000	5.8 4.4 7.4 7.3 5.7	Grid with membrane had failed after 500 passes and was no longer effective in confining the sand. Grid without membrane had failed after 1000 passes and was no longer effective in confining the sand.
Aluminum Honeycomb	6 in.	6 in.	86 lb 0.53 lb/sq ft	1-3/8 in. X 10 ft 1 in.	\$2.06/ sq ft	W/O W W	10 10 1000	4.1 3.8 7.7 7.2	Slight benefit from membrane.
Aluminum Honeycomb	6 in.	8 in.	127 lb 0.79 lb/sq ft	1-1/2 in. X 10 ft 2-5/8 in.	\$2.75/ sq ft	W/O W W/O W	10 10 1000 1000	3.6 3.7 4.2 4.6	Slight benefit from membrane.
Surface Cover Membrane	-	**	67 lb 1.7 oz/sq ft	15 X 40 ft	\$2.55/ sq ft	-	-	-	-

* Test vehicle was M54, 5-ton cargo truck with 10,000-lb gross weight and tires inflated to 70 psi. Other traffic passes shown on this summary were made with M54, 5-ton cargo truck with 20,000-lb gross weight and tires inflated to 35 psi.

** Material thickness, 0.013 in.

APPENDIX G

MEMORANDUM FOR RECORD--EVALUATION OF BORDEN AND
IKG FIBERGLASS PANELS FOR BRIDGE ACCESS/
EGRESS APPLICATIONS



DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO:
WESGS

21 August 1979

MEMORANDUM FOR RECORD

SUBJECT: Evaluation of Borden and IKG Fiberglass Panels for Bridge Access/Egress Applications

1. Reference WESGS Memorandum for Record dated 4 October 1978, subject: Traffic Tests on MSAL and M19 Landing Mats with and without T17 Membrane Underlay for Tactical Bridge Access/Egress Applications.

2. During the period of July-August 1978, both laboratory and traffic tests were conducted at the WES on Borden and IKG fiberglass panels. These investigations were conducted to determine the suitability of these materials as potential soil strengthening materials for bridge access/egress applications. It was envisioned that the use of these materials would decrease the present time in preparing access/egress in gap crossing. Therefore, during all evaluations, there was no special subgrade preparation nor was there any compaction effort applied to the soil placed in the openings of the panels. Materials used in these tests are described as follows:

a. Borden fiberglass panel. This fiberglass panel is made of completely wetted, continuous glass fibers combined with a fire-retardant polyester resin. Angular silica particles are part of the resin for a built-in, slip-resistant surface. Panel size is 4 ft wide by 12 ft long by 1 in. thick with openings of 1 by 4 in. Panel weight is 130 lb or 2.7 lb per sq ft (Incl 1).

b. IKG fiberglass panel. This fiberglass panel is made of 70 percent by weight fiberglass reinforcement, wetted and coated with polyester resin, preheated and pulled through a funnel-shaped die entrance which exerts high pressures to densify the composite and further impregnates the bundles of fiber and eliminates voids. This process is called pultrusion. Panel size is 3 ft wide by 13 ft long by 1 in. thick with openings 7/8 by 5-5/8 in. Panel weight is 97 lb or 2.5 lb per sq ft (Incl 2).

c. Kevlar membrane. This membrane is fabricated from kevlar synthetic material and is covered on each side with a thin neoprene rubber. This material was 0.013 in. thick with a weight of 1.3 lb per sq ft. It

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was supplied in 15- by 40-ft sections with a weight of 67 lb. The fiberglass panels and membrane as described above are "off-the-shelf" type items that were procured from Borden Metal Products Company, Birmingham, Alabama; IKG Industries, Nashville, Tennessee; and Reeves Bros., Inc., Rutherfordton, North Carolina, respectively. The panels did not contain end or edge connectors for positive connection between panels.

Laboratory Tests

3. Samples of the fiberglass panels were tested in the laboratory with a model 1116 Instron testing machine with a 50,000-lb capacity. The test load was applied at a speed of 0.5 in. per minute, and a stress-strain curve was recorded for each test specimen. The specimens were cut to fit within a test box which was 28 in. wide by 28 in. long by 11-1/2 in. deep. The size of the box which held the sand and test specimens was based on the physical size of the test machine. Sand was placed to a depth of 8 in. in the box prior to placing the test specimen. After the specimen was placed in the box, the voids were filled and approximately 2 in. of sand was placed over the top of the specimen. A typical test setup prior to testing is shown on Incl 3. The load head was fabricated from a 3/4-in. steel plate placed on top of a 1/4-in. plywood plate sandwiched between rubber pads (Incl 3) to simulate a tire print (approximately 93 sq in.) of an M54 5-ton truck.

4. The fiberglass panels were subjected to tests, both with and without Kevlar membrane placed beneath the panels. Tests were also conducted on river and concrete sand without any reinforcing materials. Concrete sand was used for the laboratory tests and also for the traffic tests as it was more readily available, and it is similar to river sand (Incl 4). Load-deflection curves for the sand and the fiberglass panel materials are shown on Incls 5 and 6, respectively. Various laboratory tests were also conducted on the Kevlar membrane alone. Results of these tests are given on Incl 7.

5. A summary of the laboratory tests conducted on sand and the fiberglass panels is given on Incl 8. The deflection at 6000-lb load is shown for each item tested. This load was used for comparison since this is the equivalent single-wheel load of the dual tandem wheel loading of the M54 5-ton cargo truck with gross weight of 40,000 lb. The deflection of the IKG panel with membrane at the 6000-lb load was slightly less (0.10 in.) than the panel without membrane. However, the deflection for the Borden panel with membrane was slightly more (0.04 in.) than the panel without membrane. At maximum load, the panels with the membrane supported this load with less deflection than the panels without membrane. The panels were not failed at the maximum load (50,000-lb capacity of the test machine). The results of these laboratory tests indicate that by using either the Borden or IKG panels to reinforce the sand, the

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load-carrying capacity of the overall system is approximately 10 times that of the sand alone.

Traffic Tests

Test section 1

6. The test sections for this preliminary investigation were located under a hangar-type structure to provide protection from the elements. Prior to the traffic tests of the Borden and IKI panels, a test section was prepared with a sand subgrade with no reinforcing materials embedded in the sand. However, one panel each of Borden and IKI was placed at the end and on top of the section for preliminary traffic. This section was prepared to obtain comparisons between a loosely placed sand without reinforcing materials and test sections with reinforcing materials. The depth of the sand was 20 in. Traffic was applied with the M54 cargo truck (Incl 9) with 22,000 lb gross weight on 11X20, 12-ply tires, inflated to 35 psi. Traffic was applied in a channelized pattern similar to that which would be encountered in actual road conditions. The section, after 10 passes and at the beginning of the 11th pass, is shown on Incl 10. The rut depth on the unsurfaced portion was 7 to 8 in. After 50 passes on the section (Incl 11), the rut depth varied from 11 to 12 in., and the rear housing of the truck was touching the sand subgrade. The section was reworked and leveled (Incl 12). The M54 truck with 40,000-lb gross weight and 40-psi tire pressure was then used as the traffic vehicle. The loaded M54 truck became immobilized in the loose sand in an attempt to make a pass through the test section (Incl 13). After the truck left the rut/maneuver area at the end of the section, it continued approximately 20 ft in the loose sand prior to being immobilized. The rut depth was greater than 12 in. along the test section after the truck was removed (Incl 14). There were several areas where the undercarriage of the truck had dug on the subgrade. A summary of the results of unsurfaced and surfaced sand subgrade in the preliminary test section is given on Incl 15.

Test section 2

7. The subgrade of this test section consisted of a loosely placed concrete sand for a depth of 12 in. This sand was leveled with Incl 15. The area covered by this test section was 30 ft long and 20 ft wide and consisted of items 1-4 as shown on Incl 16. Incl 16 is a view of the test section subgrade with Kevlar membrane placed on items 2 and 3 prior to placement of the fiberglass panels. Items 1 and 2 contained the Borden fiberglass panels, and items 3 and 4 contained the IKI panels.

8. The individual panels were placed onto the test section by two men (Incl 16). The panels were flexible; however, there was a permanent

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set in the panels after they were placed as they were relatively flat on the test subgrade. A completed test section of panels prior to placement of the 2-in. overlay of sand is shown on Incl 19. The panels did not contain edge connectors thus they could not be joined together. Sand was placed in the panels with a front end loader from the edges of the test section (Incl 20). Hand tools were then used to spread and level the sand over the panels. A view of the completed test section is shown on Incl 21. This evaluation of the fiberglass panels and combinations with membrane were trafficked with the test vehicle (20,000 lb gross load) described in paragraph 5. Elevation measurements of the test section surface (cross section and profile) were recorded before, during, and after traffic to determine permanent deformation of the test section and to reveal the amount of roughness. The profile readings were taken along the wheel paths of the test vehicle. Visual observation of the test materials were recorded throughout the period of traffic and supplemented by photographs.

9. A view of the test section after 10 passes of traffic with the M54 truck is shown on Incl 22. Some rutting and compaction of the section had occurred. The sand was removed from some areas of the panels; however, no damage to the panels was observed. Details of the individual items are given in the following paragraphs.

10. Item 1, Borden fiberglass panels without membrane. The surface of item 1 was rutted up to 2.2 in. after 10 passes (Incl 23). The action of the test vehicle on the panels caused some compaction and removal of the sand from the panels. As traffic continued, the panels began to work out of the sand. At 200 passes (Incl 24), all but one of the panels had come out of the sand and movement of the panels had occurred. The panels were in good condition except for one panel where some abrasion had occurred (Incl 25). The cross section (Incl 26) and profile (Incl 27) data show the condition of the surface of the test item as a result of the traffic. In an attempt to fully evaluate the panels, the panels were removed, the sand subgrade reprocessed and the panels again placed on the test section. To simulate an anchorage system, steel weights were placed along the ends of the panels. The panels were then covered with 2 in. of sand (Incl 28), and traffic was continued. After 10 passes of traffic (Incl 29), there was some movement of the sand at the edges of adjacent panels in the wheel paths of the vehicle. As traffic was continued, the action of the wheels of the test vehicle caused the sand to go through the openings in the panels. Some of this sand was forced from the wheel paths toward the panel ends; however, the majority of the sand moved toward the center of the panels. After 500 passes (700 total) (Incl 30), the center of the test section was 0.8 in. higher than at zero passes reconstructed (Incl 26, cross section data). The panels were bridging the sand subgrade as much as 3 in. (Incl 31) in the wheel paths.

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The combination of the high center and shift of the anchor weights on the end of the panels caused the panels to be bowed. Since there was no failure observed in the panels, the panels were again overfilled with 2 in. of sand (Incl 32), and traffic was continued for an additional 400 passes (1000 total) (Incl 33). The sand had moved from the top of the panels toward the center and edges of the test item. The panels were bridging the sand subgrade in the wheel paths by as much as 1-5/8 in. (Incl 34). The panels were still in good condition, and there were no failures. The maximum change in cross section (Incl 26) and profile (Incl 27) between 500 and 1000 passes was 2.0 and 1.7 in., respectively.

11. Item 2, Borden fiberglass panels with membrane. The surface of this item after 10 passes of traffic (Incl 35) was rutted as much as 2 in. The sand was removed from the panels due to the action of the test vehicle as traffic was applied. After 200 passes (Incl 36), some of the panels had worked out of the sand, and two of the panels had shifted approximately 12 in. from their original position. The membrane underneath the panels in this item prevented some movement of both the panels and sand, as compared to item 1 without the membrane. The cross-section (Incl 37) and profile (Incl 38) data show the surface roughness of this test item as a result of the traffic. After 200 passes, the panels and membrane in this item were removed, the subgrade reprocessed, and the membrane and panels relaid on the test section. The panels were then covered with 2 in. of sand and traffic was continued. There was some movement of the sand at the edges of adjacent panels in the wheel paths of the vehicle after 10 passes of traffic (Incl 39). The sand continued to move under the action of the test vehicle and after 500 passes (700 total) (Incl 40), the panels did not have any sand on them. The sand had worked its way toward the center and edges of the test section. In the wheel paths, the panels were bridging the subgrade 3 to 4 in. The center of the test section was 0.9 in. higher than at zero passes reconstructed (Incl 38, cross-section data). The combination of the high center and shift of the anchor weights caused the panels to bow. The change in the profile data from 0 to 500 passes reconstructed was small (Incl 38). There were no failures in this item, and the panels were again overfilled with 2 in. of sand as was item 1. Traffic was continued for an additional 300 passes (1000 total) (Incl 41). The sand had moved from the top of the panels toward the center and edges of the test item. The panels were bridging the sand subgrade by as much as 1-3/4 in. in the wheel paths. The panels were in good condition, and there were no failures. The maximum change in cross section (Incl 37) and profile (Incl 38) between 500 and 1000 passes was 1.6 and 1.3 in., respectively. The membrane beneath the Borden panels in this item provided only slight benefit as compared to the panels in item 1 without membrane. The change in cross section and profile in item 1 was 2.0 and 1.7 in., respectively.

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12. Item 3, IKG fiberglass panels with membrane. This item after 10 passes of traffic is shown on Incl 42. The rut depth varied up to 2.3 in. However, as traffic was applied, the action of the test vehicle on the panels caused some compaction and removal of the sand from the panels. After 700 passes of traffic (Incl 43), all but one of the panels had worked out of the sand and had shifted on the test section. The cross-section (Incl 44) and profile (Incl 45) data show the changes which occurred in the item as a result of the traffic. There was some abrasion of the panels at the edges caused by the rods which were part of the basic panels. These rods extend through the panel about 3/4 in., and the rubbing action against the adjacent panels caused the abrasion. Several of these areas are marked on Incl 43. The glue bond between some of the rods and other members (bars) of the panels had failed. Although the bond failure allowed some of the bars to shift, the panels were not considered failed. The panels and membrane were removed, the sand subgrade reprocessed, and the membrane and panels were again placed on the test section. To simulate an anchorage system, steel weights were placed along the ends of the panels. The panels were then covered with 2 in. of sand (Incl 46), and traffic was continued for an additional 300 passes (1000 total) (Incl 47). The rut depth ranged up to 3.4 in. The sand was removed in the wheel paths of four of the seven panels in the item. This sand under the action of the wheels of the test vehicle went through the openings in the panels and also was forced toward the panel ends and toward the center of the test item. There were some splits in the bars of the panels in the wheel paths. These are marked on Incl 47. However, the panels were not considered failed after 1000 passes. The maximum change in cross section (Incl 44) and profile (Incl 45) between 700 and 1000 passes was 2.7 and 1.9 in., respectively.

13. Item 4, IKG fiberglass panels without membrane. The surface of this item after 10 passes of traffic (Incl 48) was rutted as much as 2.8 in. The action of the test vehicle wheel caused some of the sand to be removed from some of the panels. As traffic was continued, the panels worked out of the sand. The panels after 700 passes of traffic are shown on Incl 49. They were in good condition except for abrasion at the panel edges (marked on Incl 49 and close-up shown on Incl 50). This abrasion was caused by the panel rods that extend at the edges, rubbing against the adjacent panels as the test vehicle wheel passed over the panels. The cross-section (Incl 51) and profile (Incl 52) data show the changes which occurred in this item as a result of traffic. The panels in this item were removed as in item 3, the subgrade reprocessed, and the panels again placed on the test section. Steel weights were placed along the edges of the panels as in item 3, the subgrade reprocessed, and the panels again placed on the test section. Steel weights were placed along the edges of the panels as in item 3 to simulate an anchorage system. The panels were then covered with 2 in. of sand (Incl 46), and traffic

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was continued for an additional 300 passes (1000 total) (Incl 53). The panels, except for the one at the end of the section, remained covered with sand. The rut depth varied up to 4.5 in. at the end of 1000 passes of traffic. The maximum change in cross section (Incl 51) and profile (Incl 52) between 700 and 1000 passes was 2.9 and 1.2 in., respectively. The panels were in good condition and were not considered failed after 1000 passes of traffic.

Test section 3

14. The test section which covered an area 13 ft wide and 48 ft long was excavated to a depth of 24 in. and backfilled with a heavy clay. The test section, which consisted of items 1-4 (Incl 54), was surfaced with Borden and IKG fiberglass panels. These panels were tested with Kevlar membrane on top of and beneath the panels (Incl 55). To simulate an anchorage system, steel weights were placed along the ends of the panels in all four items in the test section. An approach area was placed at each end of the test section to provide a maneuver area for the test vehicle during application of traffic. The in-place CBR of the subgrade prior to traffic was an average of 1.6 for the top 12 in. Soil data are summarized on Incl 56.

15. The traffic tests were conducted with an M54 5-ton military cargo truck with gross weight of 40,000 lb on 11XP0, 12-ply tires, inflated to 70 psi. These conditions represent the highway loading for the truck. Traffic was applied in a channelized pattern similar to that which would be encountered in actual road conditions. Elevation measurements of the test section surface (cross section and profile) were recorded before, during, and after traffic to determine permanent deformation of the test section and to reveal the amount of roughness. The profile readings were taken along the wheel paths of the test vehicle. Visual observation of the test materials were recorded throughout the period of traffic and supplemented by photographs.

16. Item 1, Borden fiberglass panels with membrane on top. Item 1 prior to traffic is shown on Incl 57. As traffic was applied, the panels deflected and tended to embed in the soft subgrade; however, when the wheels of the test vehicle left the items, the panels pulled out of the subgrade. The weights on the panel edges prevented the subgrade from flowing to the edges of the item. However, the subgrade built up at the center of the item with rutting in the wheel paths. Some of the subgrade extruded up through the openings in the panels. Elevation measurements and cross-section (Incl 58) and profile (Incl 59) data show the changes which occurred as traffic was applied. The item after 1500 passes of traffic is shown on Incl 60. The membrane had wrinkled in the wheel paths and was torn at the end of the item. The torn areas are marked on

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Incl 60. Straight-edge measurements were made and in the wheel paths, deviations of as much as 4 in. were recorded. The weights were removed after 154 passes in order to observe the action of the panels under traffic on low strength subgrade without weights. As traffic was continued, the panels deflected under the wheel load, and the subgrade was forced toward the center of the test item from the paths. After the test vehicle left the panels, the panels returned to a near flat condition and were bridging the subgrade in the wheel paths. After 550 passes, the panels had shifted on the test section (Incl 61). The membrane was torn in the wheel paths of the test vehicle. The panels were bridging the subgrade as much as 7 in. in the wheel paths (Incl 62). Cross-section (Incl 58) and profile (Incl 59) data show the changes in elevation which occurred as traffic continued from 154 to 550 passes although there was no panel failure. As the truck passed over the panels, the undercarriage of the truck was close to touching the panels along the center line of the item. The subgrade was rutted in the wheel paths as some of it had worked toward the center of the section and this added to the bowing of the panels at the center. The cross section of the subgrade in item 1 after 550 passes is shown on Incl 63.

17. Item 2, Borden fiberglass panels with membrane beneath the panels. Item 2 prior to traffic is shown on Incl 64. As traffic was applied, the panels deflected under the wheel load, and the subgrade began to rut in the wheel paths and build up near the center of the section between the wheel paths. The weights on the end of the panels prevented the movement of subgrade toward the edge of the section. The elevation measurements and cross-section (Incl 65) and profile (Incl 66) data show the changes which occurred as traffic was applied. The item after 154 passes of traffic is shown on Incl 67. The panels were bridging the subgrade as much as 4 in. in the wheel paths. A typical measurement is shown on Incl 68. The membrane was not torn as a result of the traffic. However, it was wrinkled as it had moved toward the center of the test item under the action of the load wheel on the panels. Straight-edge measurements were made and in the wheel paths, deviations of as much as 4 in. were recorded. There were no splits nor was there any indication of any distress in the panels after 154 passes. The weights were removed as they were in item 1 after 154 passes, and traffic was resumed. The panels were not connected along the edges since they did not have integral connectors, and they shifted under the action of the test vehicle. The membrane migrated from the edges of the section toward the center. The panels in the wheel path tended to embed in the subgrade as the vehicle passed over them. However, the subgrade in the wheel paths was rutted, and the panels tended to return to their flat position (a permanent set as a result of the deflection under the load wheel) after the passage of the vehicle. Some of the subgrade material remained in the panel openings. After 500 passes of traffic, 1/2-in.-thick steel

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cables were used to tie the panels together to prevent them from shifting on the test item and/or separating. As traffic was continued, the edge members of two panels began to tear away from the body of the panels. After 550 passes (Incl 69), the edge members were split and torn and traffic was discontinued. The test vehicle is shown on Incl 70 (note that the differential of the vehicle is almost touching the panels), and a close-up of one of the failed areas is shown on Incl 71. The panels were bridging the subgrade as much as 7 in. as shown on this inclosure. The changes in cross section and profile from 154 to 550 passes are shown on Incls 65 and 66, respectively. The cross section of the subgrade for this item after 55 passes is shown on Incl 72. The cross-section profile measurements for item 2 (with membrane beneath panels) between 0 and 154 passes (weights on end of panels) was 0.6 in. less than that for item 1 (membrane on top of panels). Both items had about the same change in cross section between 154 (weights removed) and 550 passes (2.1 in. for item 1 and 2.3 in. for item 2). The change in profile measurements for item 2 between 154 and 550 passes was 0.8 in. less than for item 1. Therefore, with the membrane placed beneath the panels, there was less change in elevation.

18. Item 3, IKG fiberglass panels with membrane beneath the panels. Item 3 prior to traffic is shown on Incl 73. The subgrade beneath the wheel paths rutted as traffic was applied. The panels deflected under the wheel load and tended to level as the load was removed. This flexing of the panels caused the glue bond between the rods and the bars of the panels to fail. The bars then shifted as the test vehicle trafficked the panels. The subgrade material shifted toward the center of the section. The panels were bridging the subgrade as much as 4-1/2 in. at 154 passes. Traffic was discontinued at 154 passes (Incl 74) as the panels were considered failed. Splits in the bars are marked on this inclosure. Some of the bars were also broken (Incl 75). Cross-section (Incl 76) and profile (Incl 77) measurements show the changes which occurred as traffic was applied. The panels were removed from the test item and replaced with landing mat so that traffic could continue on items 1 and 2.

19. Item 4, IKG fiberglass panels with membrane on top of panels. A view of this item prior to traffic is shown on Incl 78. As traffic was applied, the subgrade was forced up through the openings in the panels and the panels became embedded in the subgrade. As traffic was applied, the subgrade material beneath the wheel paths tended to move toward the center line and outside edges of the test section resulting in rutting of the test section. Traffic was discontinued after 154 passes of traffic (Incl 79) as the panels were considered failed. Straight-edge measurements were made in the wheel paths and deviations of as much as 4-1/2 in. were recorded. Changes in elevation (cross-section and profile data) were also recorded during the tests (Incls 80 and 81). The membrane

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was removed from the top of the panels (Incl 32). The panels were split and broken similar to those in Item 3. The membrane was not torn or ripped as a result of the failed panels. Inclusion 33 is a close-up of the condition of the panels in one wheel path.

20. Results of this investigation are as follows:

a. In laboratory tests by using the Borden or IKG panels to reinforce the sand, the load-carrying capacity is approximately 10 times that of the sand alone.

b. The average deflection measurement in the laboratory tests of the IKG panel specimen with membrane at the equivalent single-wheel load (6000 lb) was 0.1 in. less than that for a panel specimen without membrane. However at the maximum load (50,000 lb), the panel specimen with the membrane beneath it deflected 0.6 in. less than the panel specimen without membrane.

c. The deflection in the laboratory tests of the Borden panel specimen with membrane at the equivalent single-wheel load (6000 lb) was 0.04 in. more than it was for the panel specimen without membrane. At the maximum load (50,000 lb), the panel specimen with the membrane beneath it deflected 0.19 in. less than the panel specimen without membrane.

Test section 1

d. The M54 cargo truck with 20,000-lb gross load and tires inflated to 35 psi made 50 passes on a loose sand subgrade prior to the undercarriage of the vehicle dragging the subgrade.

e. The M54 cargo truck with 40,000-lb gross load and tires inflated to 70 psi could not make any passes on a loose sand subgrade as it became immobile due to deep wheel ruts and contact between the undercarriage of the vehicle and the subgrade.

Test section 2

f. The action of the test vehicle (20,000-lb gross load) after 200 passes on the Borden panels with and without membrane had caused the panels to work out of the sand. Some panels had gotten on top of each other; therefore, traffic was stopped and the section reworked. The panels were replaced on the section, steel weights were added along the edges to simulate an anchorage system, and the panels were overfilled with 2 in. of sand. After an additional 500 passes (700 total), the sand no longer covered the panels in the traffic lane. The panels were again covered with 2 in. of sand, and traffic continued until an additional 300 passes

WJMS

11 August 1963

SUBJECT: Evaluation of Borden and IKG Fiberglass Panels for Pipeline Access/Egress Applications

(1000 total) were completed. The panels both with and without membrane were still trafficable although the panels were out of the sand in the traffic lane. The ends of the panels remained anchored and covered with sand. The panels with and without the membrane were bridging the subgrade by 1-3/4 and 1-1/2 in., respectively. The maximum change in cross section and profile for the Borden panels without membrane was 2.0 and 1.7 in., respectively. The maximum change in cross section and profile with membrane was 1.6 and 1.3 in., respectively.

g. The action of the test vehicle (20,000-lb gross load) after 700 passes on the IKG panel with and without membrane had caused the panels to work out of the sand. Some of the panels had gotten on top of each other; therefore, traffic was stopped and the section reworked. The membrane and panels were then placed on the section, steel weights were placed along the edges to simulate an anchorage system, and the panels were over-filled with 2 in. of sand. An additional 300 passes (1000 total) of traffic were applied. The panels with the membrane were still trafficable although the panels were out of the sand in the traffic lane. The panel ends remained anchored and covered with sand. The panels without the membrane were also trafficable and remained covered with sand. The maximum change in cross section and profile for the IKG panels without membrane was 2.9 and 1.8 in., respectively. The maximum change in cross section and profile with membrane was 2.7 and 1.9 in., respectively.

Test section 3

h. The IKG panels both with membrane on top of and beneath the panels were failed after 154 passes of the test vehicle with 40,000-lb gross load on a clay subgrade with a CBR of 1.6.

i. The Borden panels with membrane on top of the panels were not failed although they were bridging the subgrade in the wheel paths by as much as 7 in., and they had shifted on the subgrade after 550 passes of the test vehicle (40,000-lb gross load). However, the membrane was failed in the vehicle wheel paths as it was torn.

j. The Borden panels with membrane beneath the panels failed after 550 passes of traffic. These panels failed along the edges where they were fastened together with steel cables to prevent them from shifting after the steel anchor weights were removed. The panels were bridging the subgrade as much as 7 in. in the wheel paths, and they had shifted on the subgrade when traffic was discontinued. The membrane was not torn as a result of the traffic.

21 August 1979

SUBJECT: Evaluation of Borden and IKG Fiberglass Panels for Bridge
Access/Egress Applications

21. Conclusions and recommendations.

a. The load-carrying capacity of sand in the laboratory tests was increased approximately 10 times by reinforcing the sand with either Borden or IKG panels. However, no significant increase in the load-carrying capacity of the sand was achieved by using membrane beneath the panels.

b. A loose, uncompacted sand subgrade will support only 50 passes of an M54 cargo truck (20,000-lb gross load) with tires inflated to 35 psi and will not support any passes of the M54 cargo truck with 40,000-lb gross load and tires inflated to 70 psi. Therefore, a surfacing media is required in the field of operations of this type to support bridge access/egress operations.

c. The volume of M54 cargo truck (20,000-lb gross load) traffic that loose sand subgrade will support is increased significantly by the use of Borden and IKG panels placed on the loose sand. The Borden panel supported 100 passes of the M54 cargo truck before it required anchoring with steel weights on the panel ends. After anchoring the panels supported an additional 800 passes and were traffickable after the 1000 total passes. The IKG panels supported 700 passes of the M54 truck prior to being anchored similar to the Borden panels and after anchoring, the IKG panels supported an additional 300 passes and were traffickable after the 1000 total passes.

d. In the traffic tests with membrane placed beneath the Borden and IKG panels on a loose sand subgrade, the membrane did not provide any significant improvement in the performance of the panels.

e. Although the IKG panels, both with the membrane on top and beneath the panels on a clay subgrade with a CBR of 1.6, failed after 154 passes of the test vehicle with 40,000-lb gross load, this was an improvement over the number of passes (10 on a subgrade of 1.5 CBR, reference in paragraph 1) that the vehicle can make without any surfacing.

f. The Borden panels with membrane on top supported a significant number of passes, 550, as compared to a subgrade with no surfacing (10 on a subgrade of 1.5 CBR, reference in paragraph 1). The membrane did not appear to have influenced the number of passes that the panels supported as the membrane was failed as a result of being torn in the wheel paths. The panels were not failed; however, no further traffic was recommended since the undercarriage of the test vehicle was almost dragging the surface of the panels. This was due to rutting of the subgrade beneath the panels in the wheel paths.

MEMOS

31 August 1969

SUBJECT: Evaluation of Borden and IK3 Fiberglass Panels for Helicopter
Access/Egress Applications

g. Although the Borden panels with the membrane beneath the panels on clay subgrade with a CBR of 1.0 were failed after 550 passes, this was a significant improvement over the number of passes (10 on a subgrade of 1.5 CBR, reference in paragraph 1) that the vehicle can make without any surfacing. The panel failures were caused by the cable used to fasten the panels together at the edges in an attempt to prevent them from shifting on the test section during traffic. The membrane did not appear to have influenced the number of passes the panels supported.

h. It is recommended that:

(1) The Borden and IK3 panels be further developed to include integral side connectors.

(2) A method of anchoring the panels be developed.

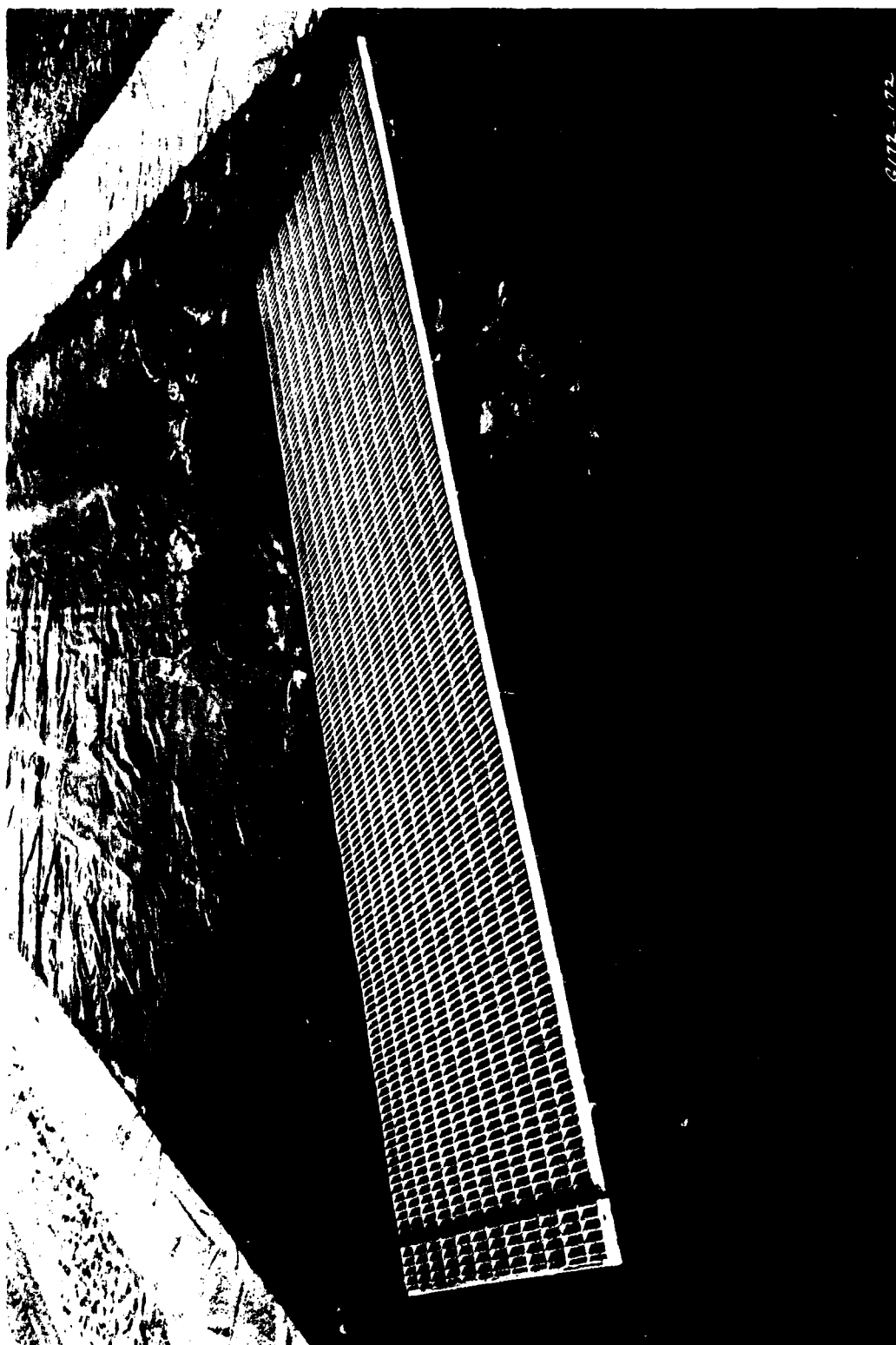
(3) The redesigned Borden panels be tested both on a loose sand and a weak (1.0 - 2.0 CBR) clay subgrade with the M54 cargo truck with gross load of 40,000 lb and tires inflated to 70 psi.

(4) The redesigned IK3 panels be tested on a loose sand and weak with the M54 cargo truck with gross load of 40,000 lb and tires inflated to 70 psi.

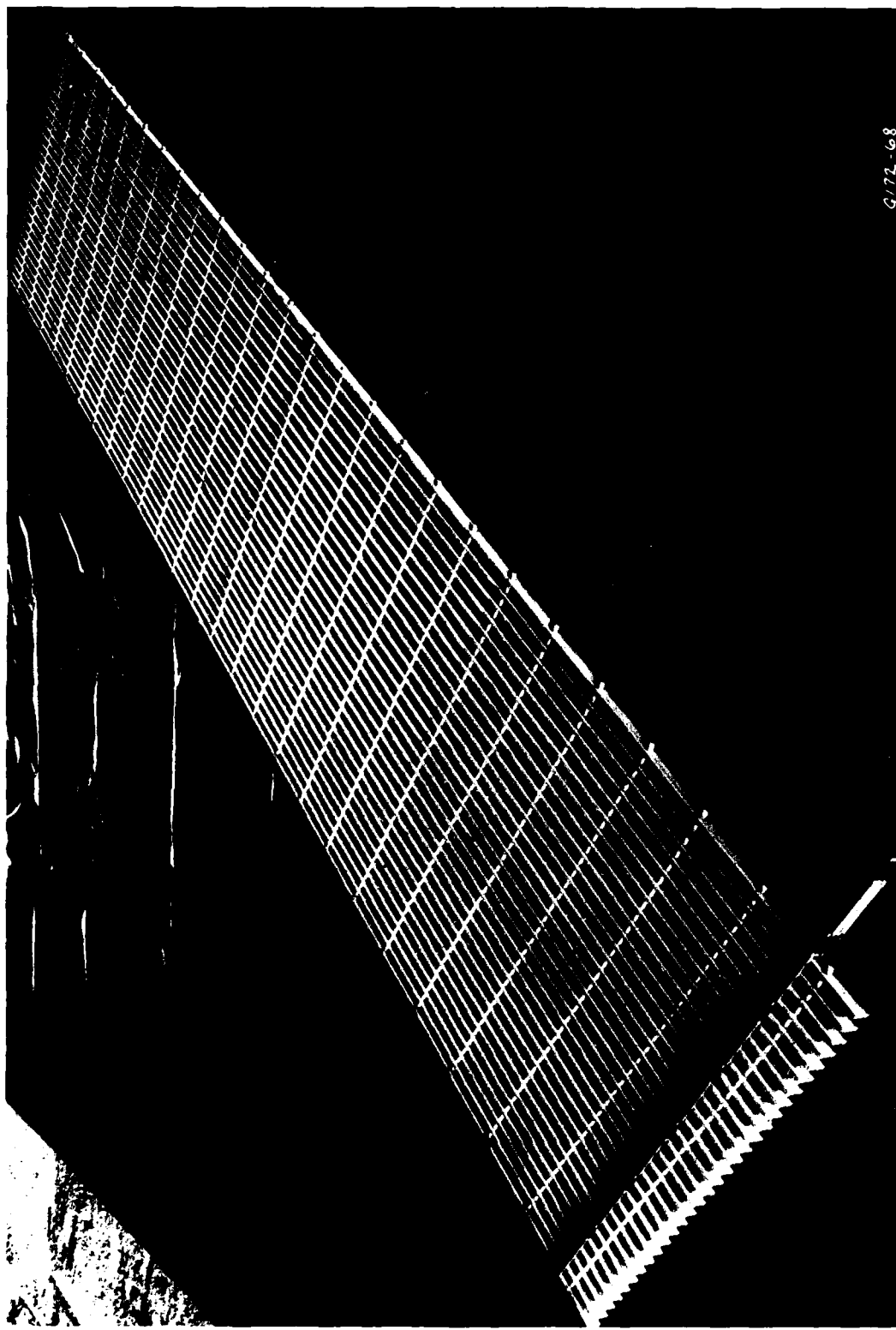
83 Incl
as

Dwight W. White

DWIGHT W. WHITE
Engineer
Landing Mat Branch
Material Development Div



Borden fiberglass panel

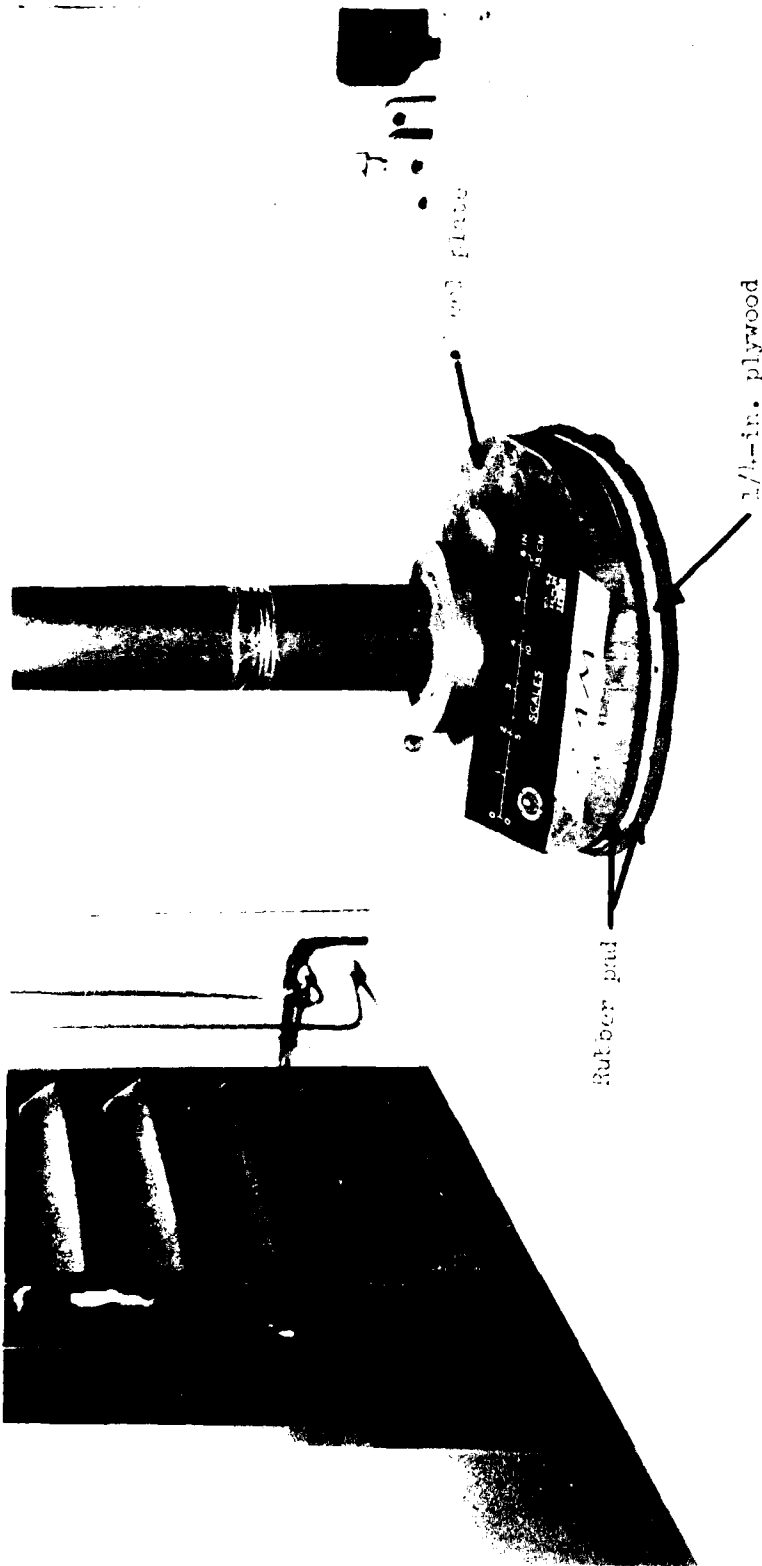


G172-68

IKG fiberglass panel

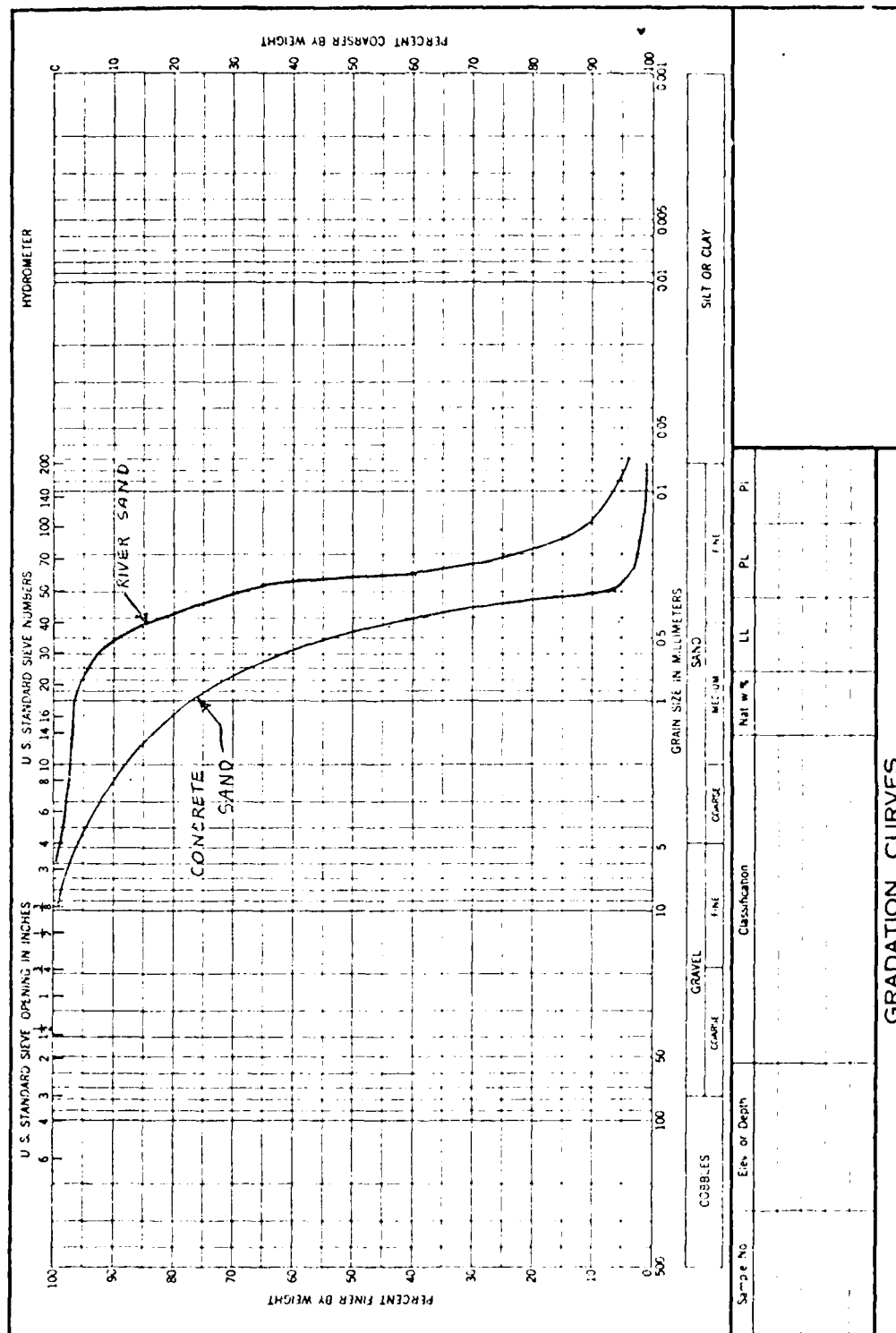
Panel 2.

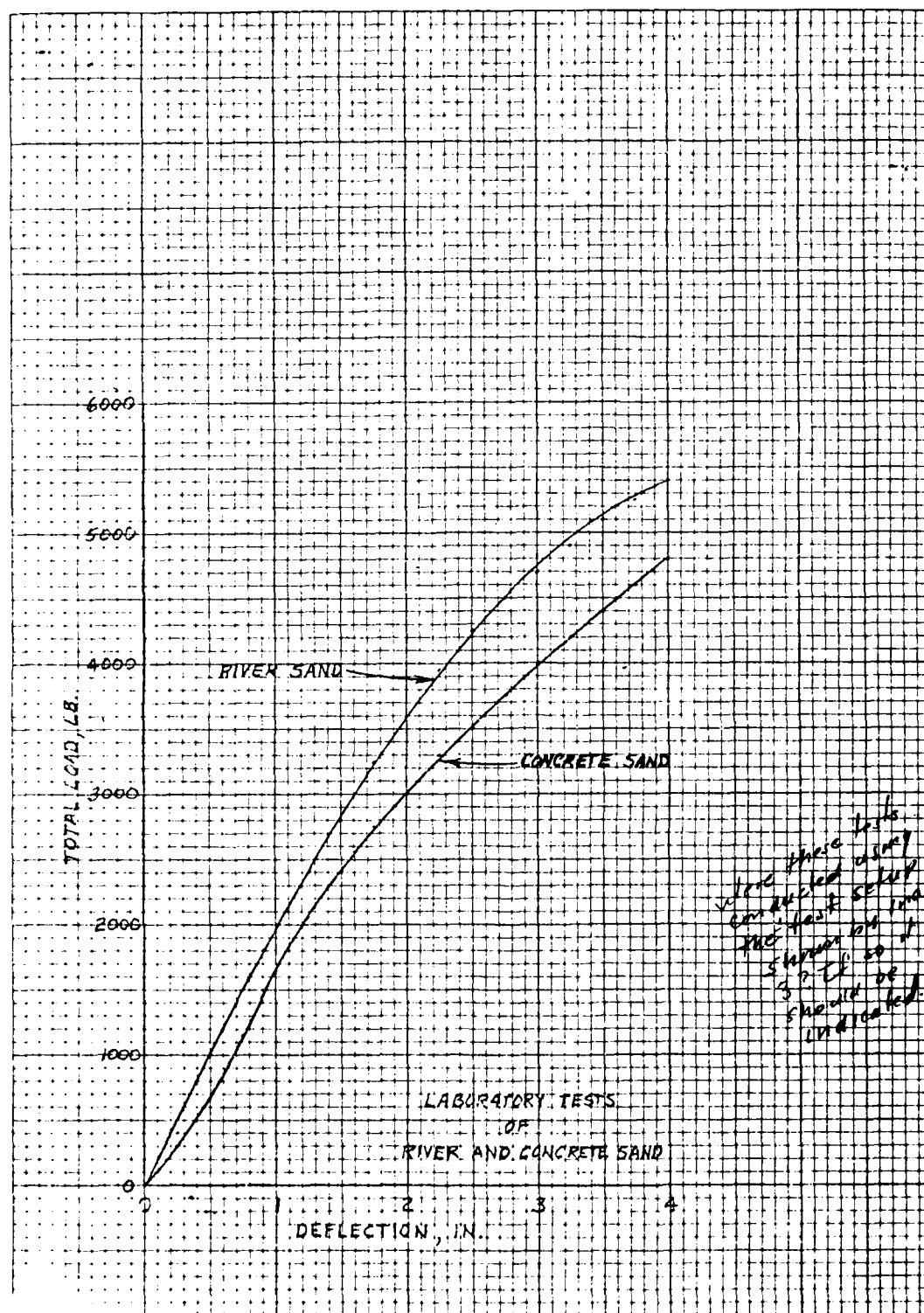
315



Laboratory test set-up prior to test

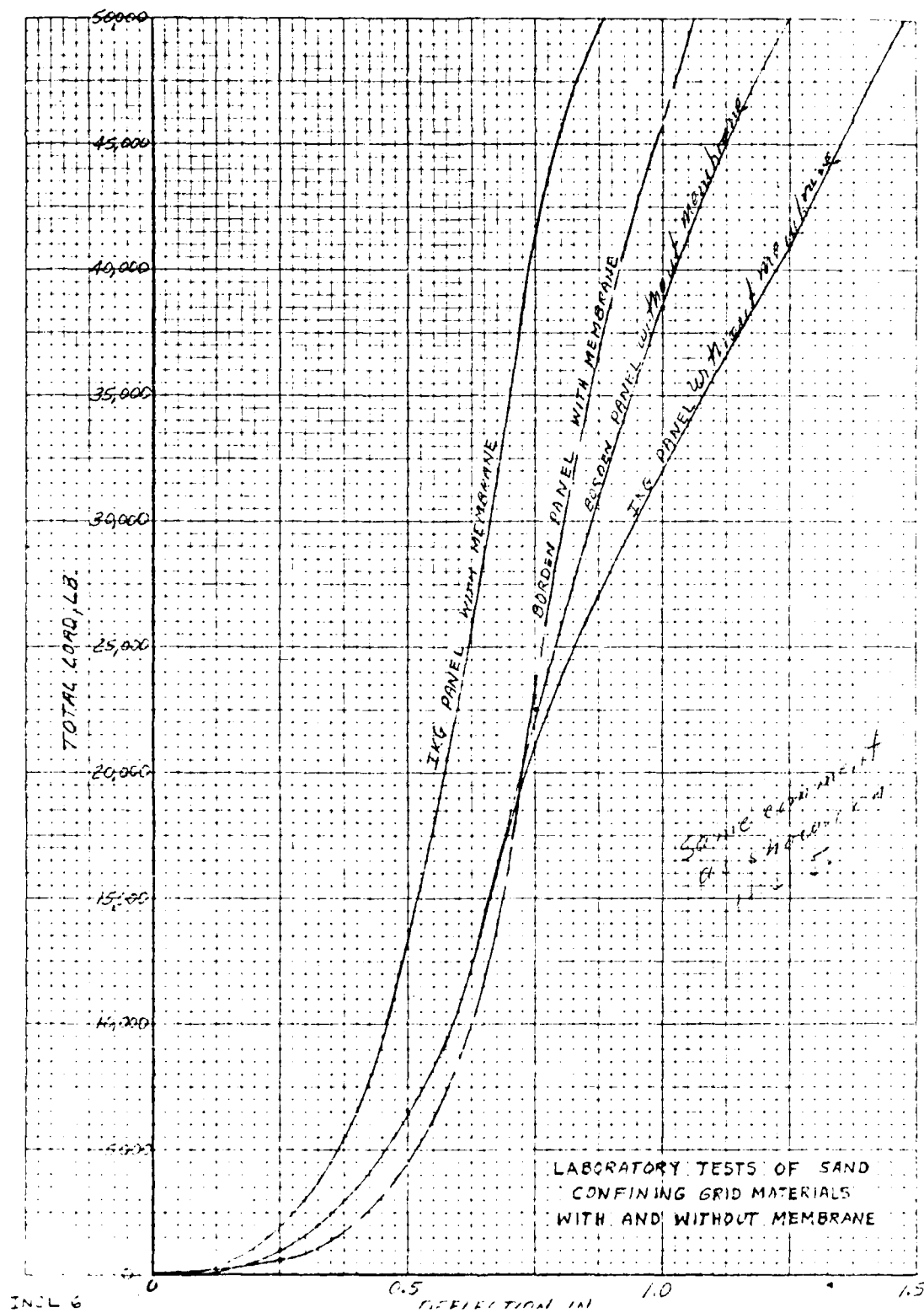
INCL 4





done these tasks
conducted using
the test setup
shown in and
3. If so it
should be
indicated.

INCL 5



Fabric Testing

Product: Kevlar Fiber - B (DE 8473)

Manufacturer: Reeves Brothers, Inc.

Test and Unit of Measure	Test Method	Test Results
Weight, oz per sq yd	Fed. Test Method Std. No. 191, Method 5041	15.55
Thickness, inches	Fed. Test Method Std. No. 191, Method 5030	.013
Breaking Strength, Grab, lb	ASTM D-1682-64	Warp - 573 Fill - 440
Apparent Elongation @ Break, %	ASTM D-1682-64	Warp - 6 Fill - 7
Tear Strength, Tongue, lb	ASTM D-2261	Warp - 60 Fill - 49
Bursting Strength, Ball, psi	ASTM D-751-72	263
Joint Strength, lb		740

Note: All breaks were in fabric; no breaks in joint

Incl co

SUMMARY OF LABORATORY TESTS

Material	Panel		Opening Sizes in Panel, in.	Membrane	Deflection @ 6000 lb load, in.		Max. Load, lb*	Deflection at Max. Load, in.
	Size, ft	Depth, in.						
IKG Fiberglass	3X13	1	7/8 X 5-5/8	without	0.49		50,000	1.48
IKG Fiberglass	3X13	1	7/8 X 5-5/8	with	0.39		50,000	0.88
Borden Fiberglass	4X12	1	1 X 4	without	0.49		50,000	1.25
Borden Fiberglass	4X12	1	1 X 4	with	0.53		50,000	1.06
Concrete Sand	-	-	-	-	4.00**		-	-
River Sand	-	-	-	-	4.00#		-	-

* Capacity of machine, 50,000 lb.

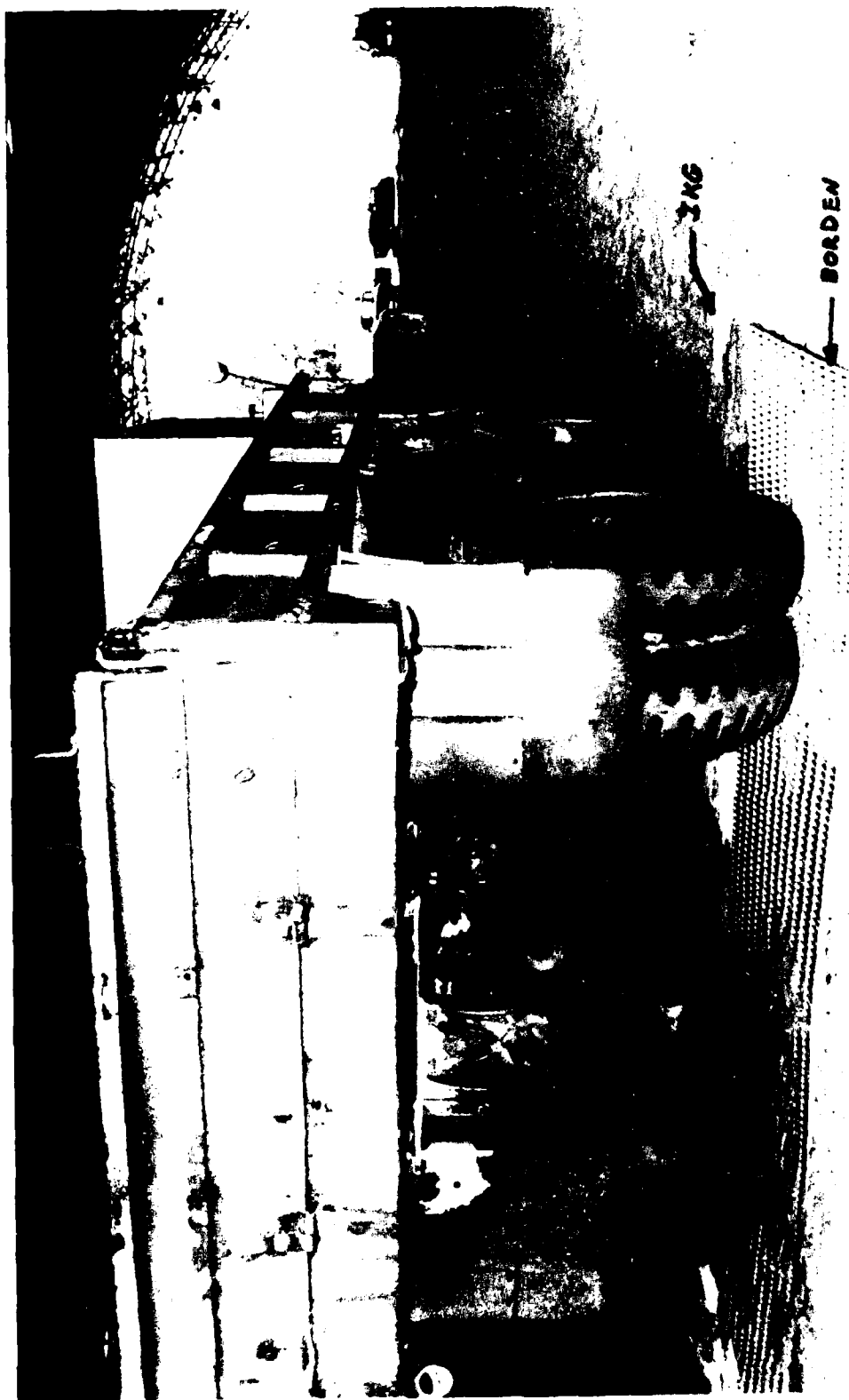
** Deflection @ 4800 lb load (did not reach 6000 lb).

Deflection @ 5400 load (did not reach 6000 lb).



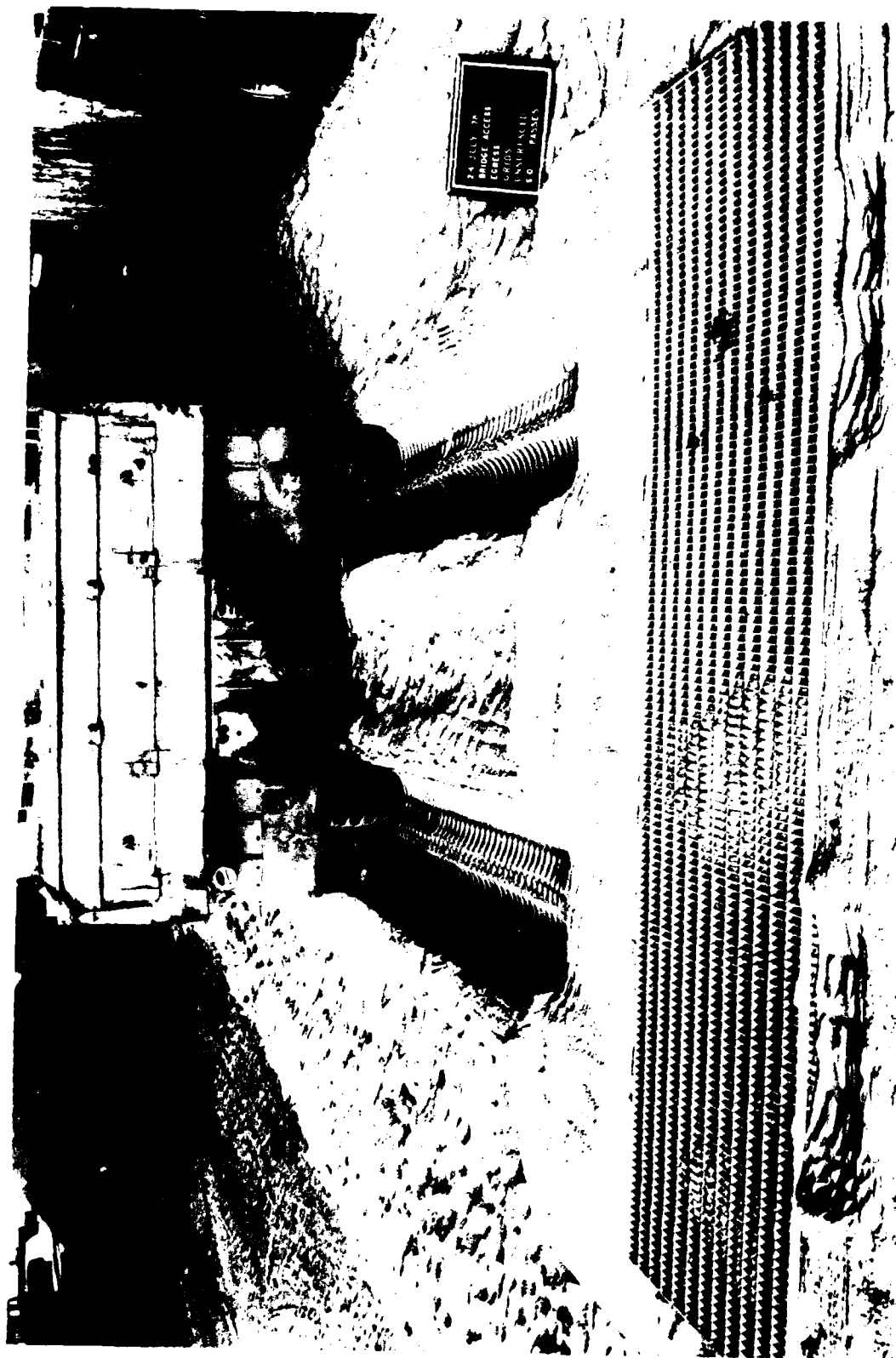
M51 cargo truck used in traffic test

Incl 2.



M54 truck on test section after 10 passes

Incl 10.

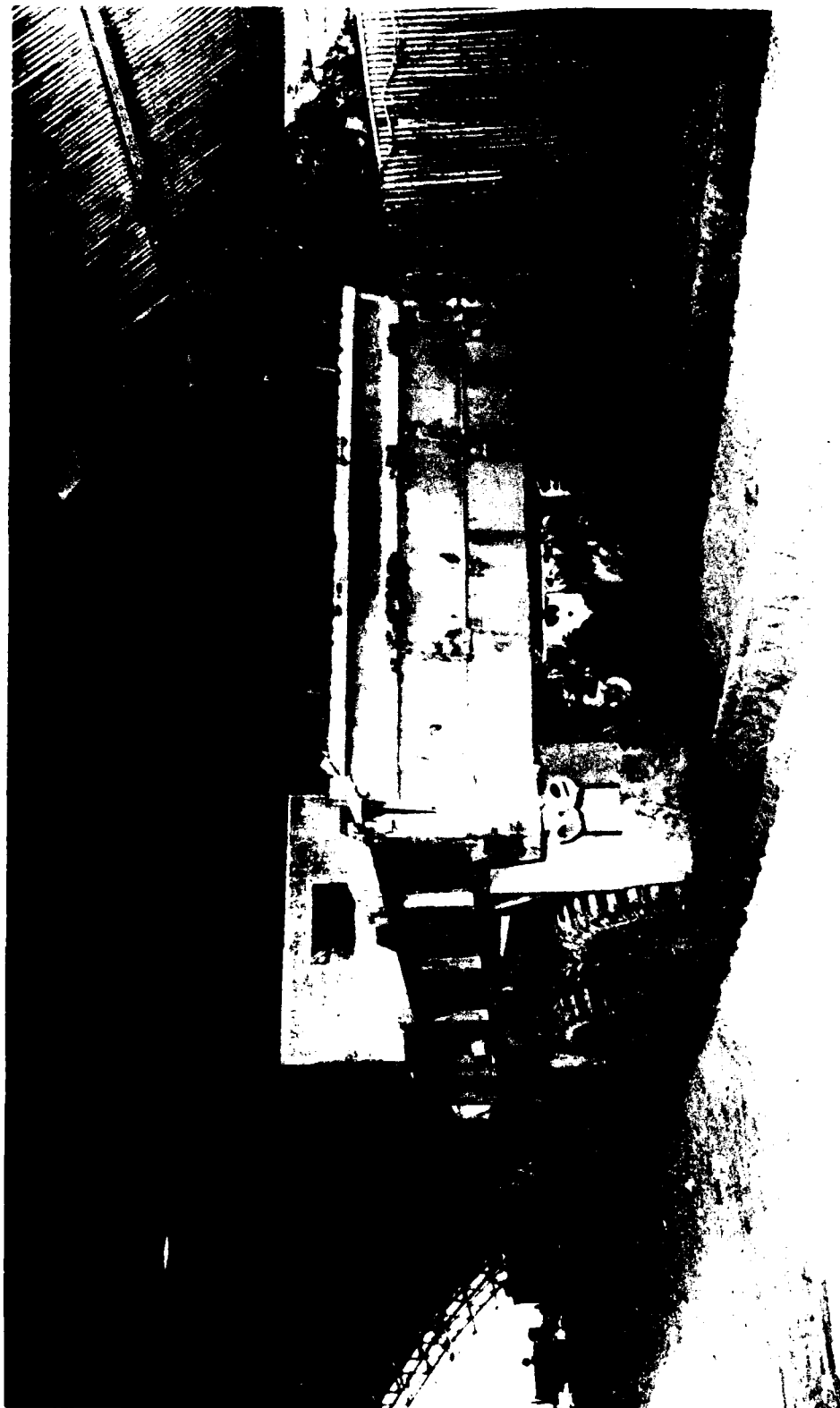


Incl 11.



Test section prior to traffic with M54 truck loaded to 40000lb gross load

Incl 12.



M54 truck immobilized in loose sand

Incl 13.

326



Truck section after 11th truck was removed

Incl 14.

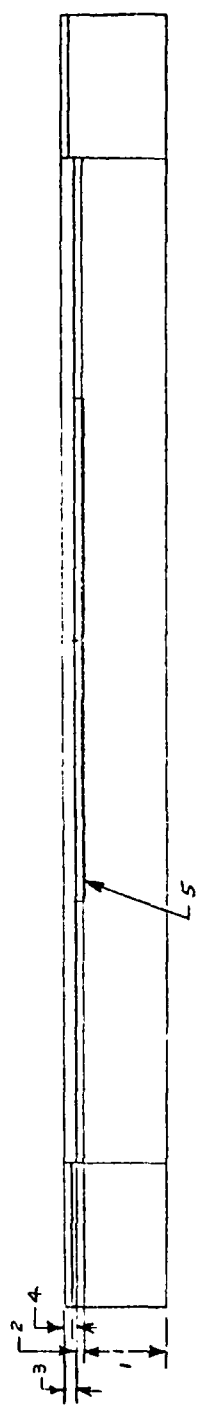
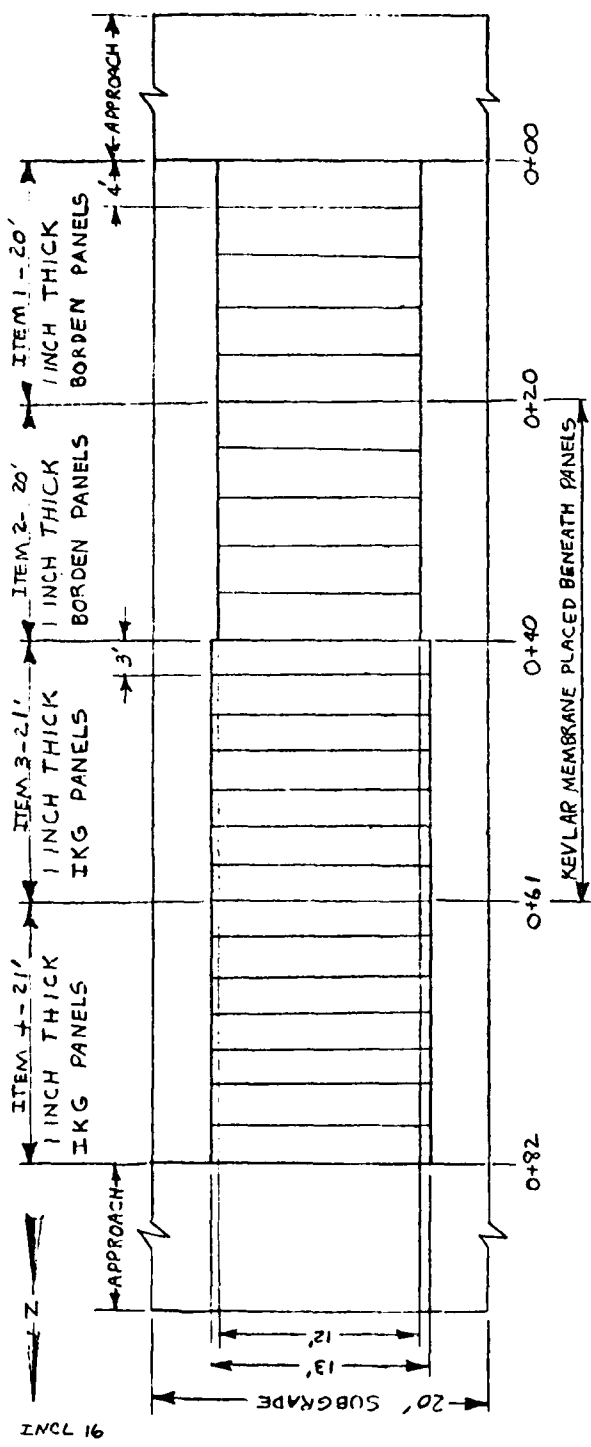
Incl 15

SUMMARY OF SAND CONFINEMENT INVESTIGATION

Materials	Grid Size	Grid Depth	Weight	Panel Size	Cost	With/ Without Membrane	Number of Passes	Rut Depth, in.	Comments
None	-	-	-	-	-	w/o	0*	12	Truck became immobilized after going about 20 ft in loose sand.
None	-	-	-	-	-	w/o	10 50	7-8 11-12	Undercarriage of truck was touching sand sub-grade after 50 passes.
IGG Fiber-glass	7/8 in. X 5-5/8 in.	1 in.	97 lb 2.5 lb/sq ft	3 ft X 13 ft	\$8.35/ sq ft	w/o w w/o w	10 10 1000 1000	2.8 2.3 4.5 3.4	After 700 passes, material worked out of sand; anchor weight added; at 1000 passes rut depth as shown at left.
Borden Fiber-glass	1 in. X 4 in.	1 in.	130 lb 2.7 lb/sq ft	4 ft X 12 ft	\$6.71/ sq ft	w/o w w/o	10 10 1000 1000	2.2 2.0	Material worked out of sand after 200 passes; anchor weights added; and after 1000 additional passes material worked out of sand.
Neoprene Kevlar Membrane	-	**	67 lb 1.8 oz/sq ft	15 ft X 40 ft	\$2.58/ sq ft	-	-	-	-

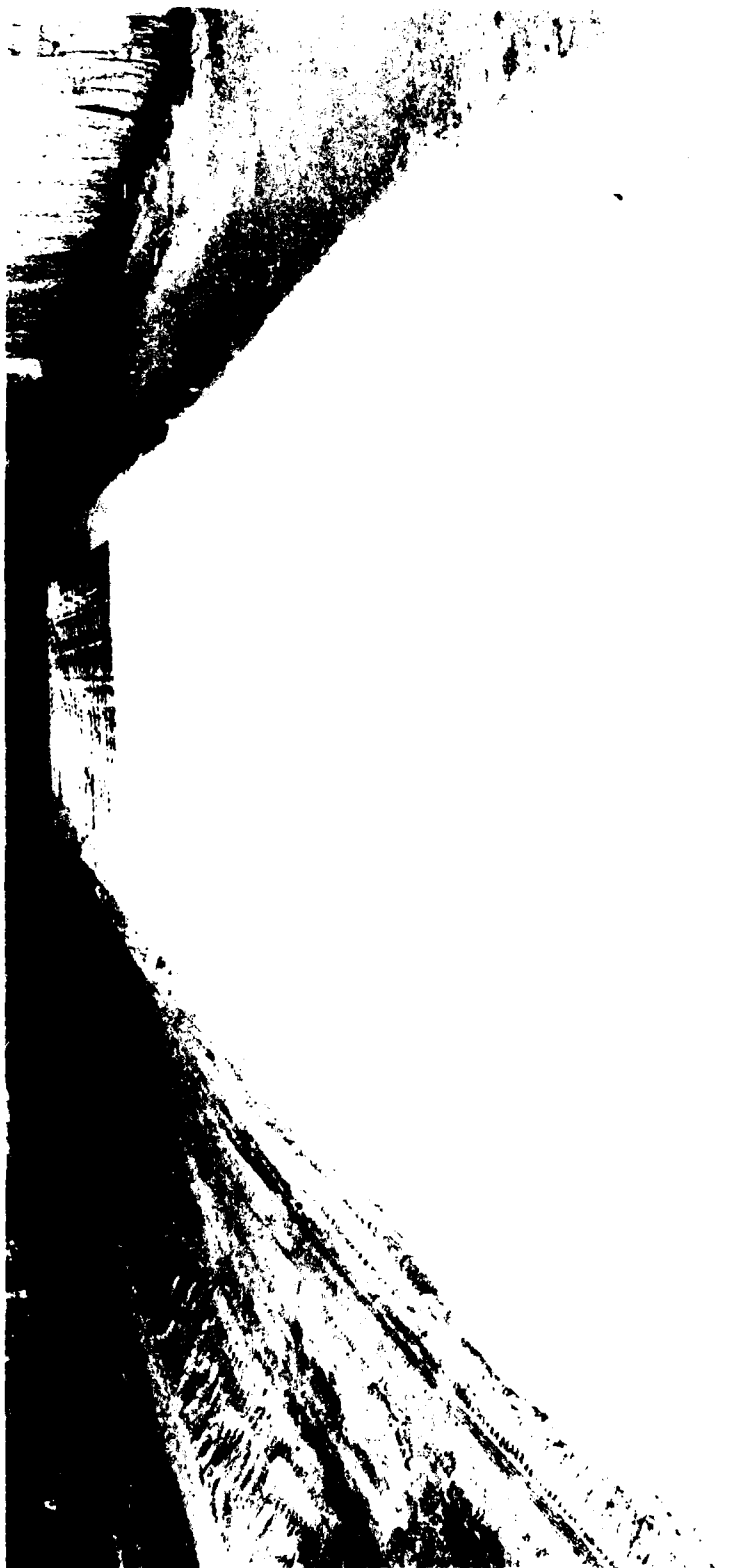
* Test vehicle was M54, 5-ton cargo truck with 40,000-lb gross weight and tires inflated to 70 psi. Other traffic passes shown in this summary were made with M54 5-ton cargo truck with 20,000-lb gross weight and tires inflated to 35 psi.

** Material thickness, 0.013 in.

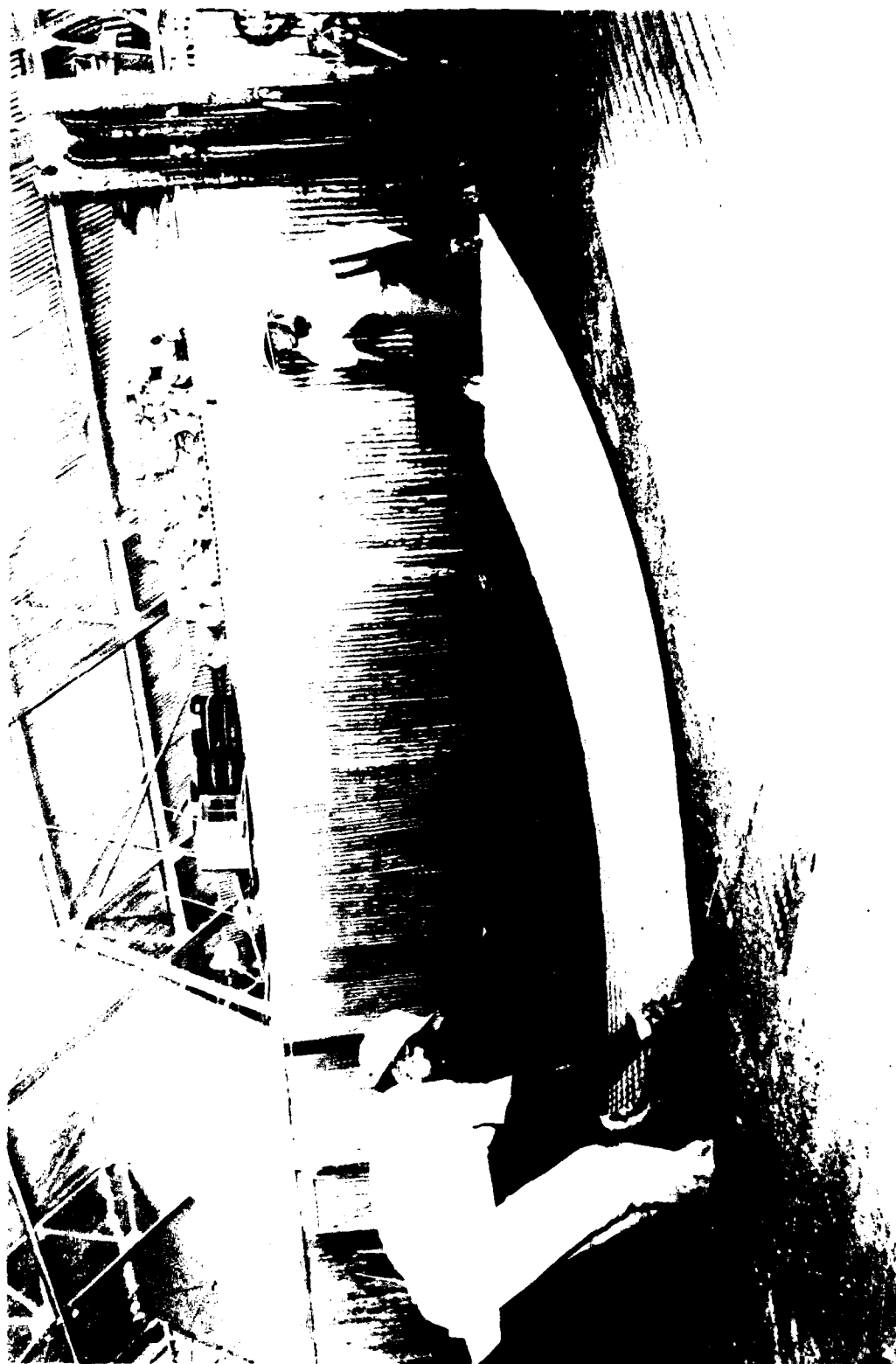


TEST SECTION LAYOUT

BORDEN AND IKG FIBERGLASS PANELS WITH/WITHOUT MEMBRANE



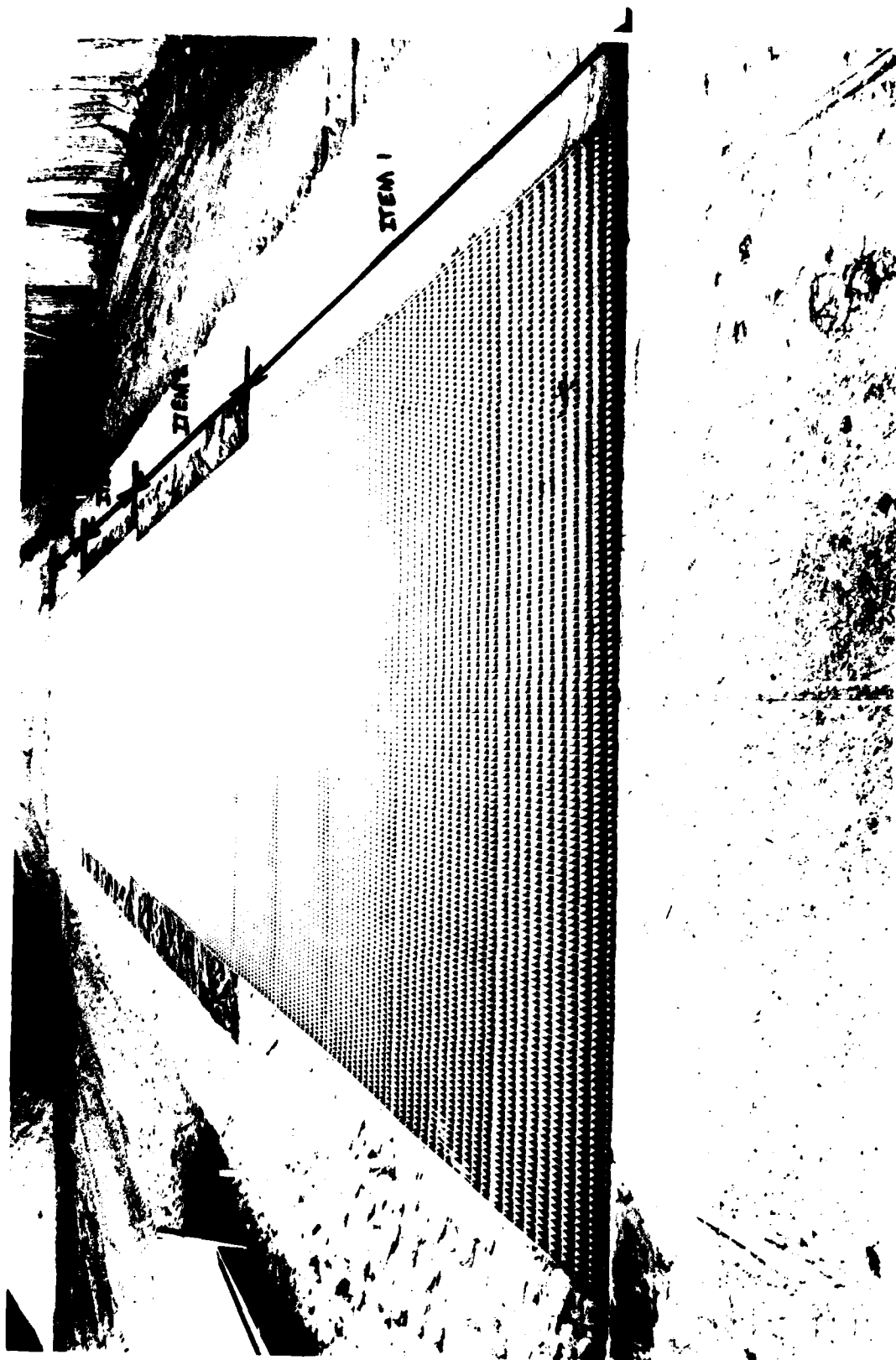
Kevlar membrane on test section prior to placement of panels



Placement of panels on test section

Incl 18.

331



Test section with panels placed prior to overfill with 2-in. sand layer



Sand placed on test section with front end loader

Incl 20.

333



Test section prior to traffic

Incl 21.

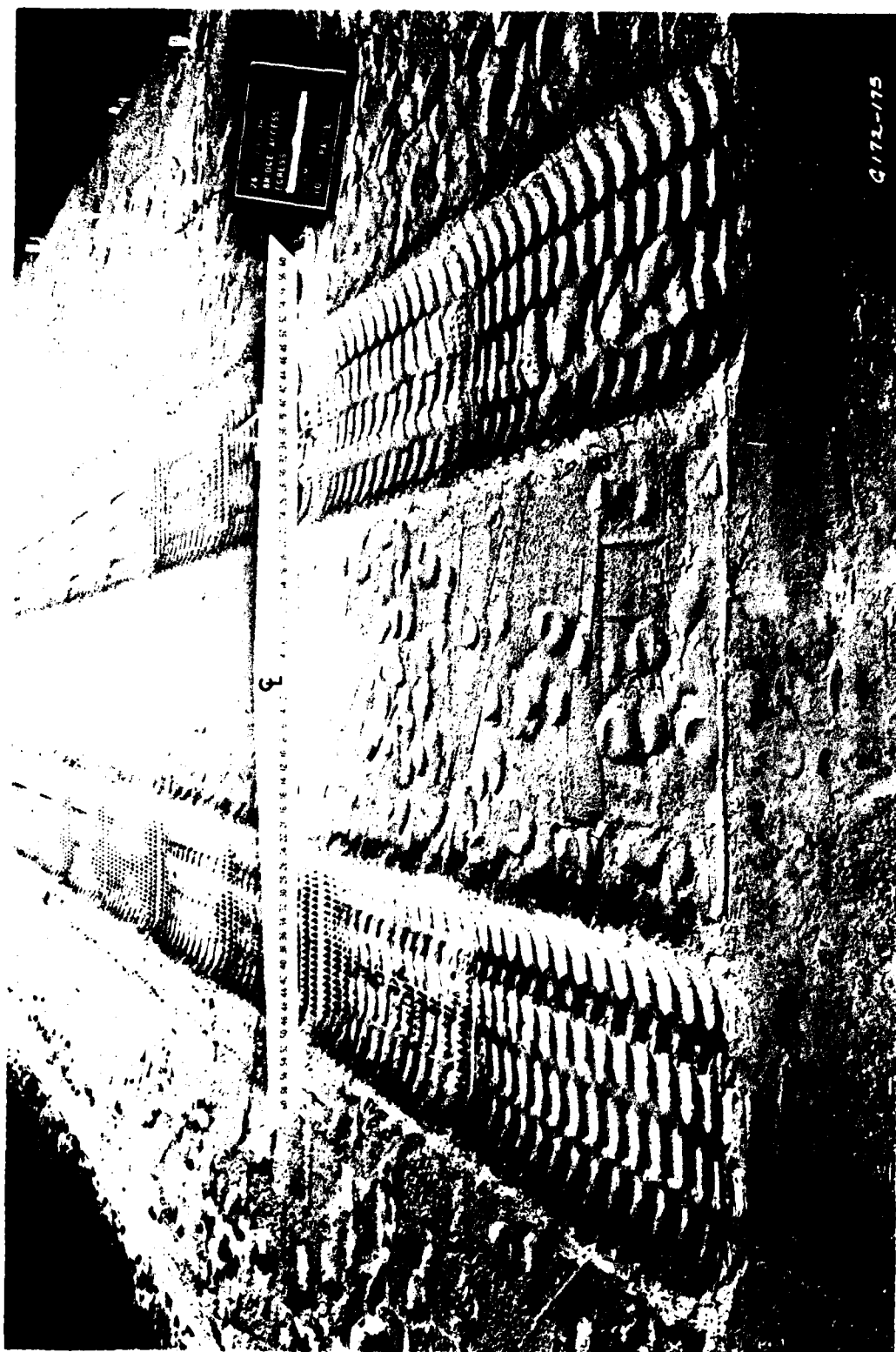
334



Test section after 10 passes of traffic

Incl 22.

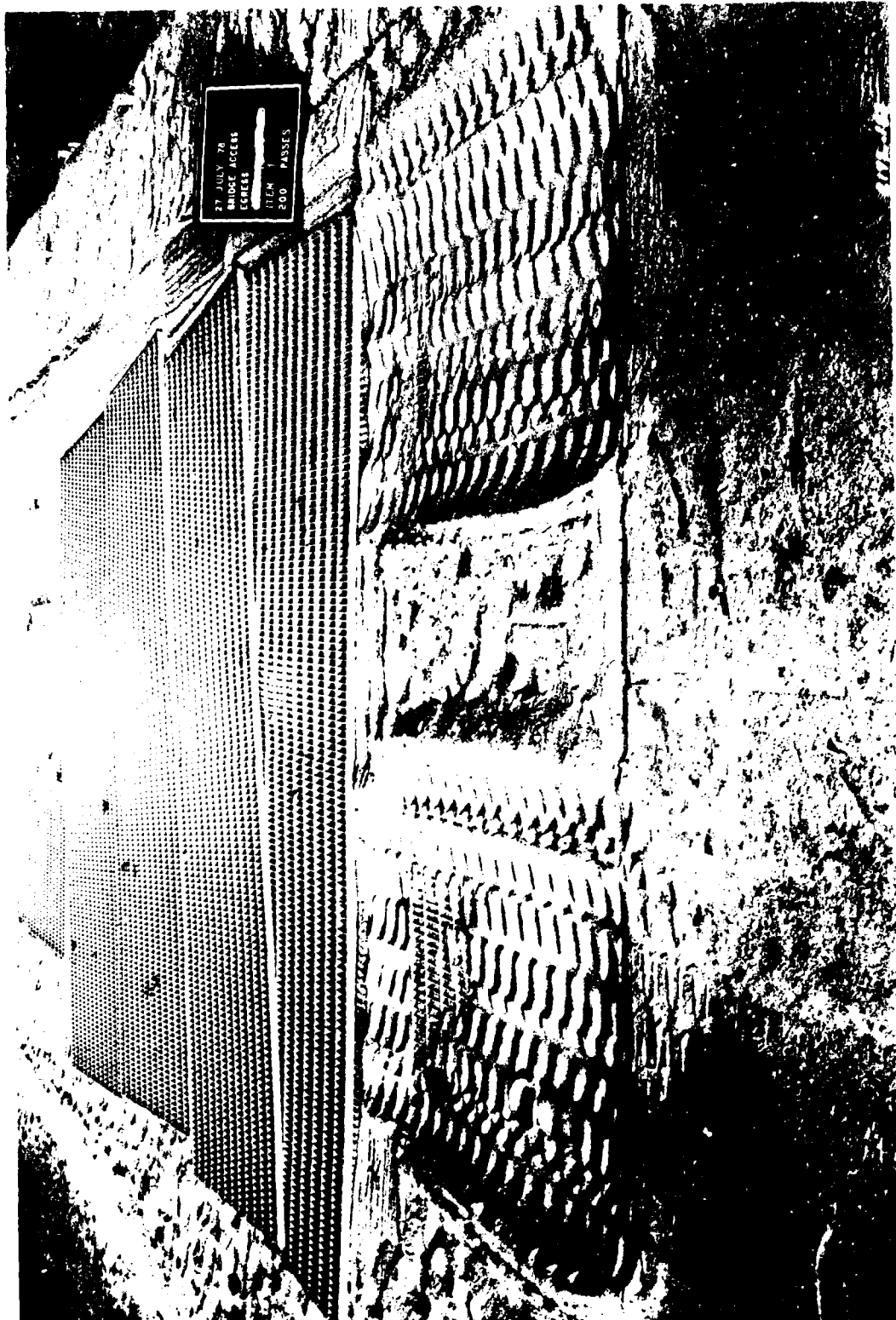
335



Item 1 after 10 passes of traffic

Incl 23.

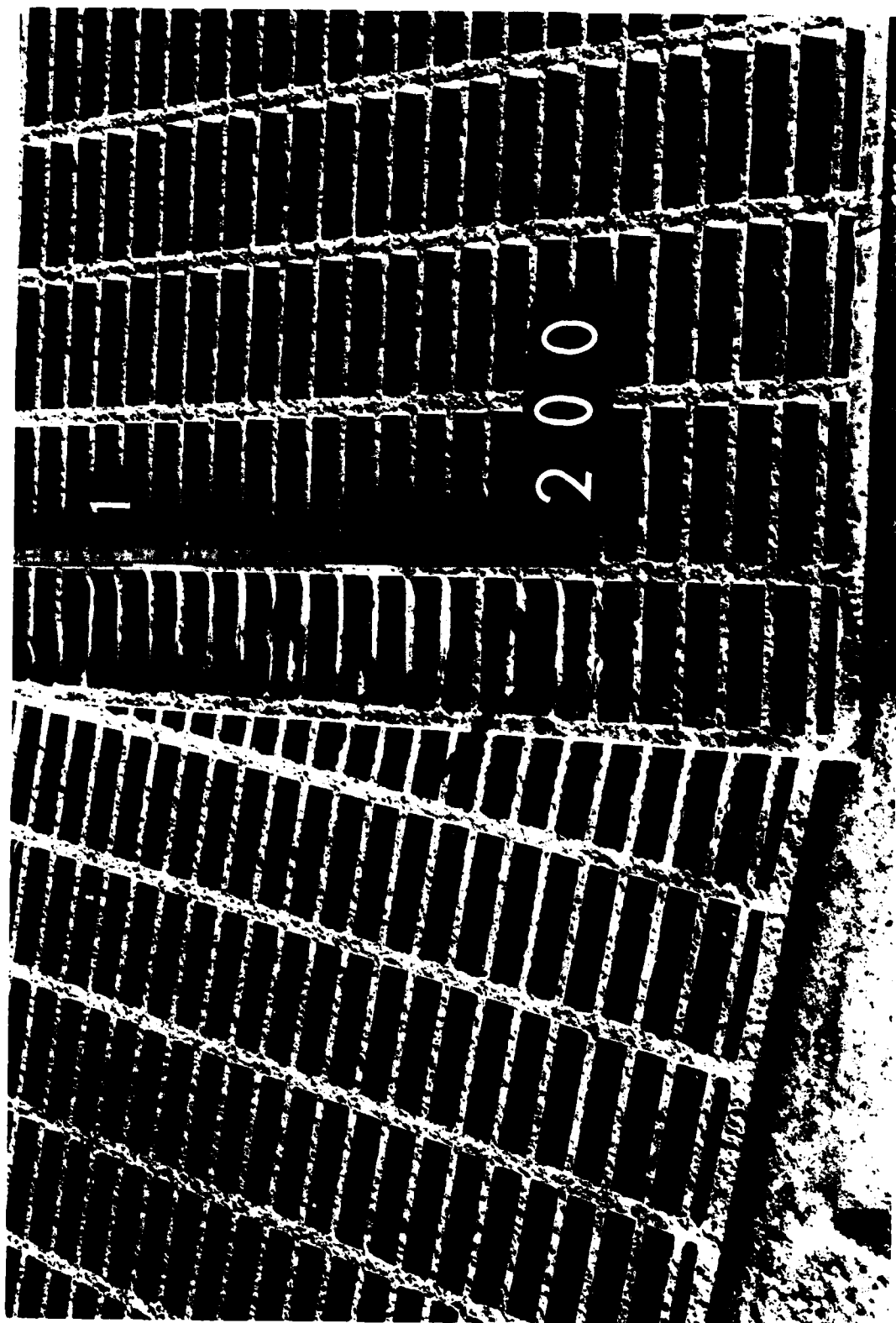
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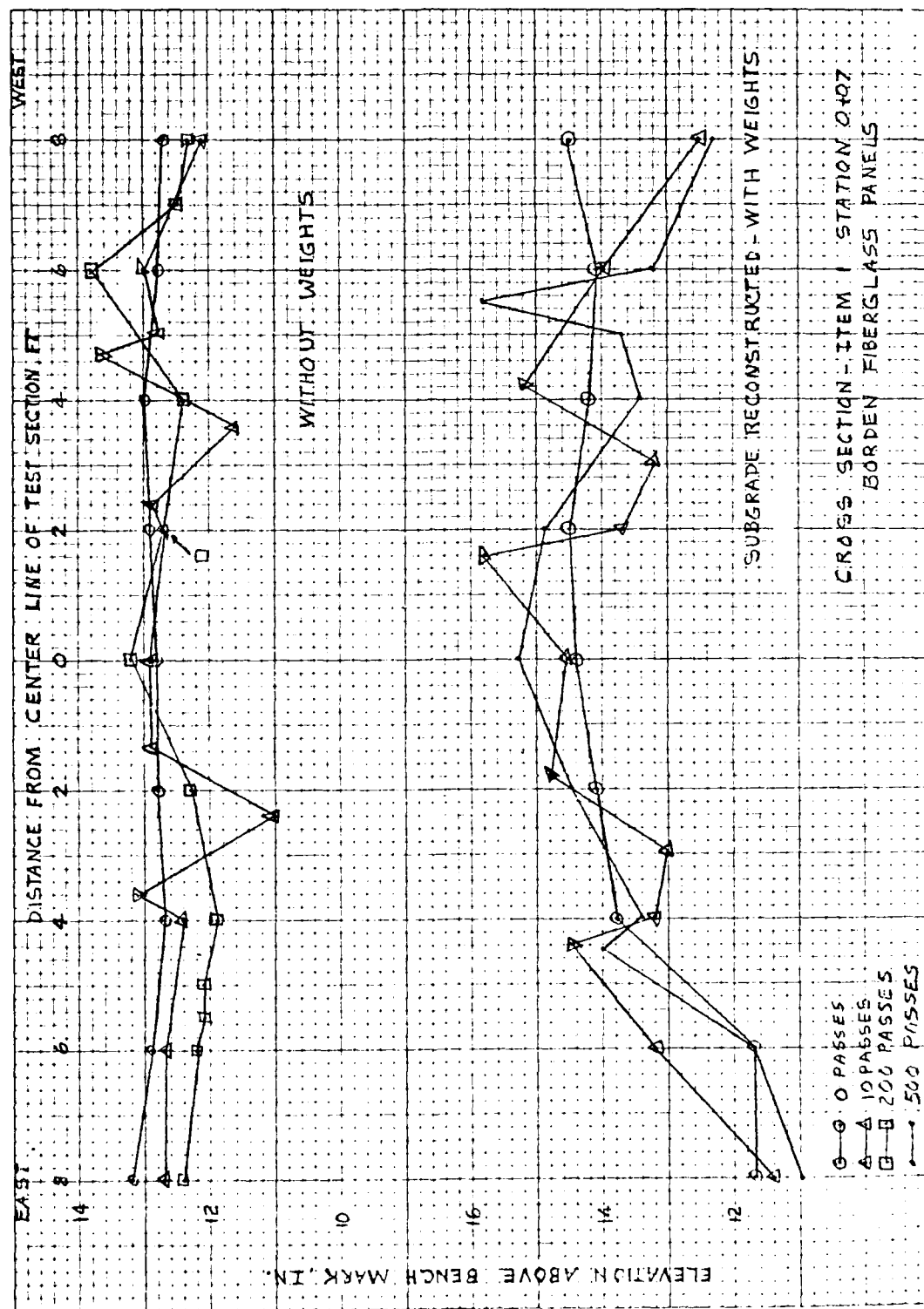
Item 1 after 200 passes of traffic

Incl 24.

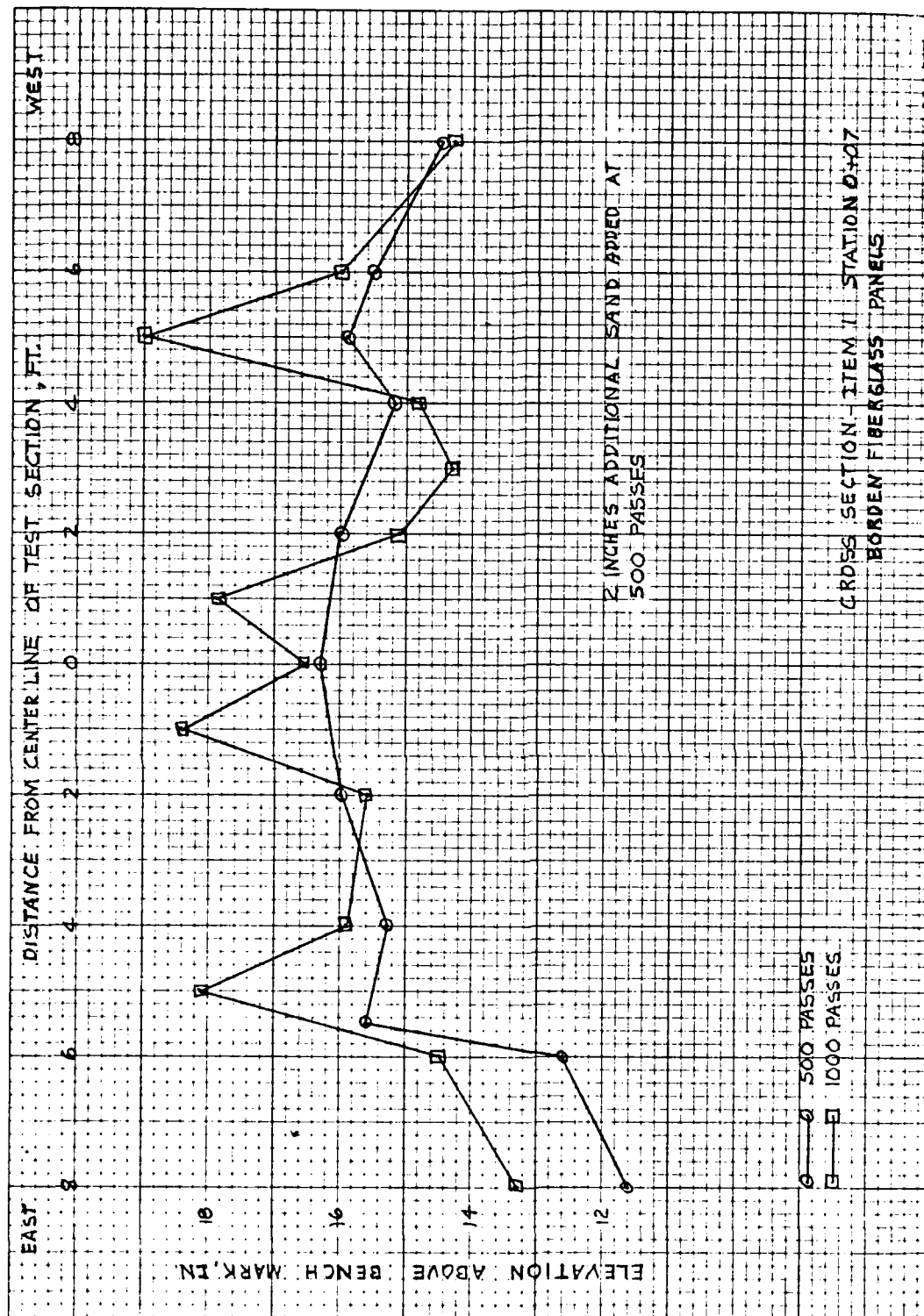
337



Abrasive wear on panel in item 1 after 200 passes of traffic

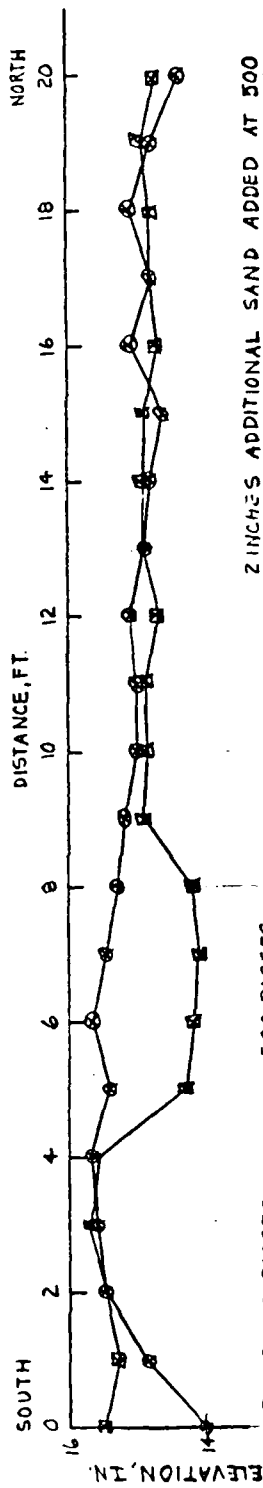
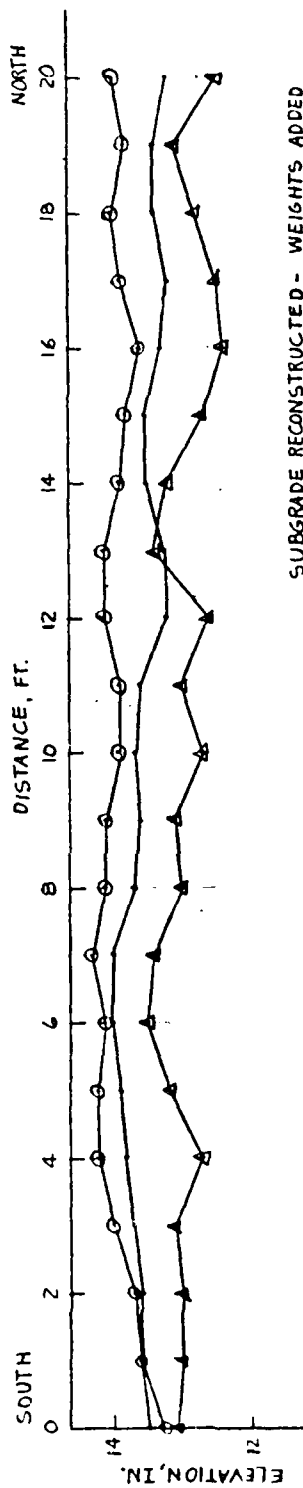
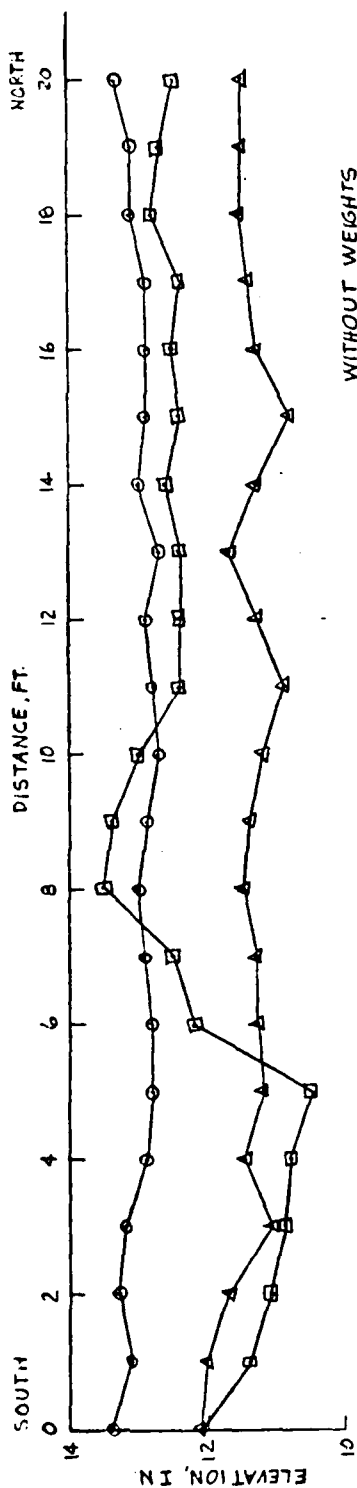


INCL 26 PAGE 2



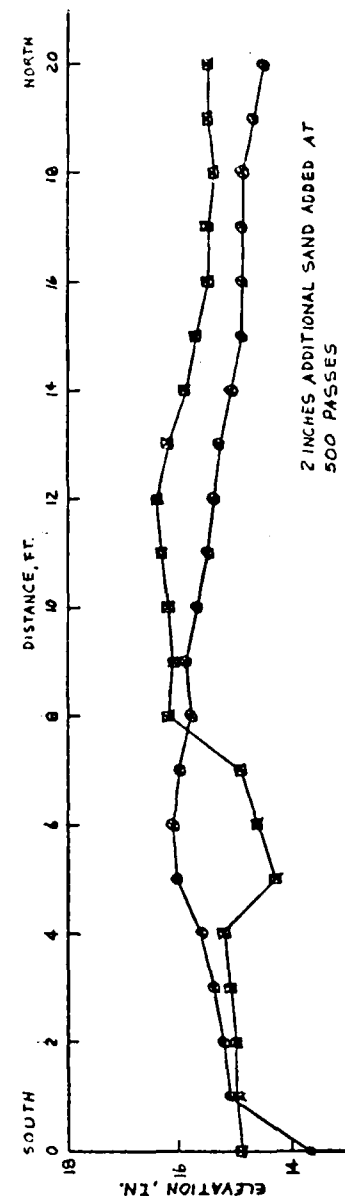
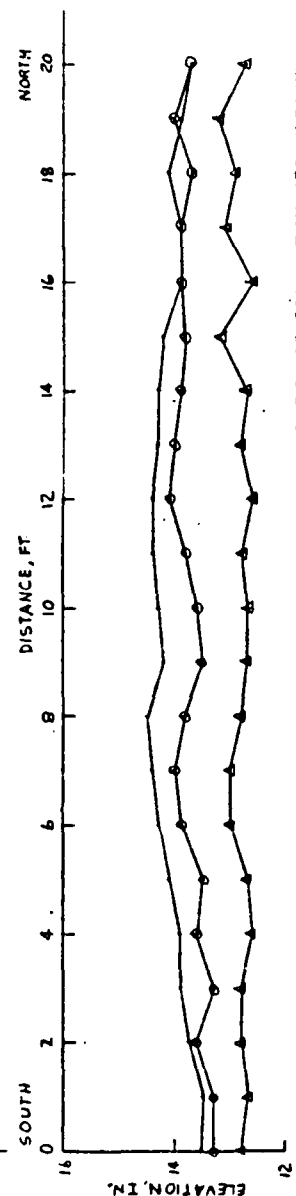
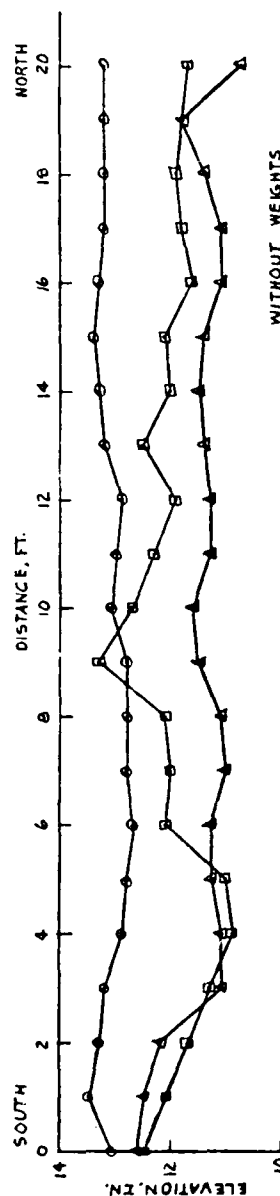
2 INCHES ADDITIONAL SAND ADDED AT 500 PASSES

GROSS SECTION ITEM 11 STATION 0+07
BORDEN FIBERGLASS PANELS



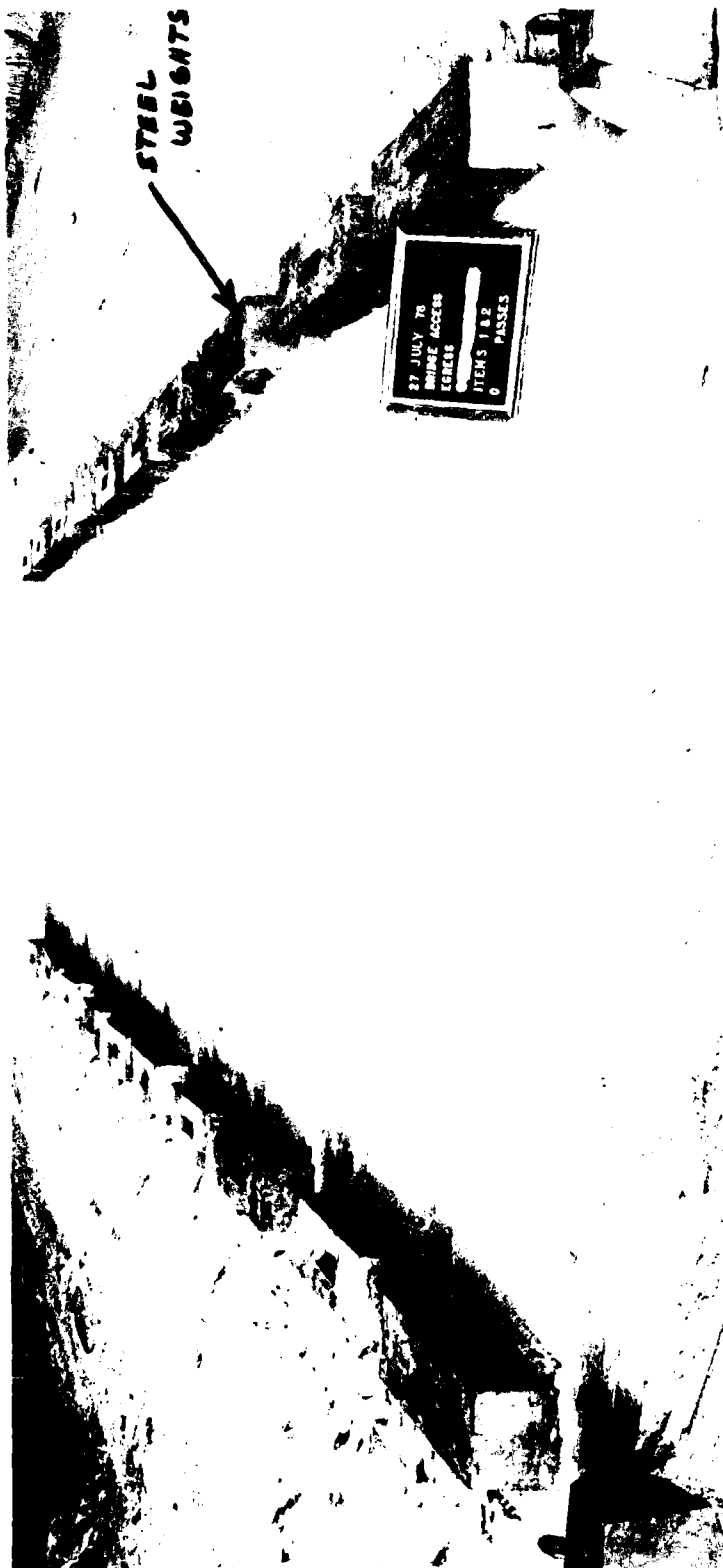
PROFILE-ITEM 1- LEFT WHEEL PATH
BORDEN FIBERGLASS PANELS

- 0 PASSES
- △ 10 PASSES
- 200 PASSES
- 500 PASSES
- 500 PASSES
- △ 500 PASSES
- 1000 PASSES



○ 0 PASSES
 △ 10 PASSES
 ● 500 PASSES
 ■ 1000 PASSES

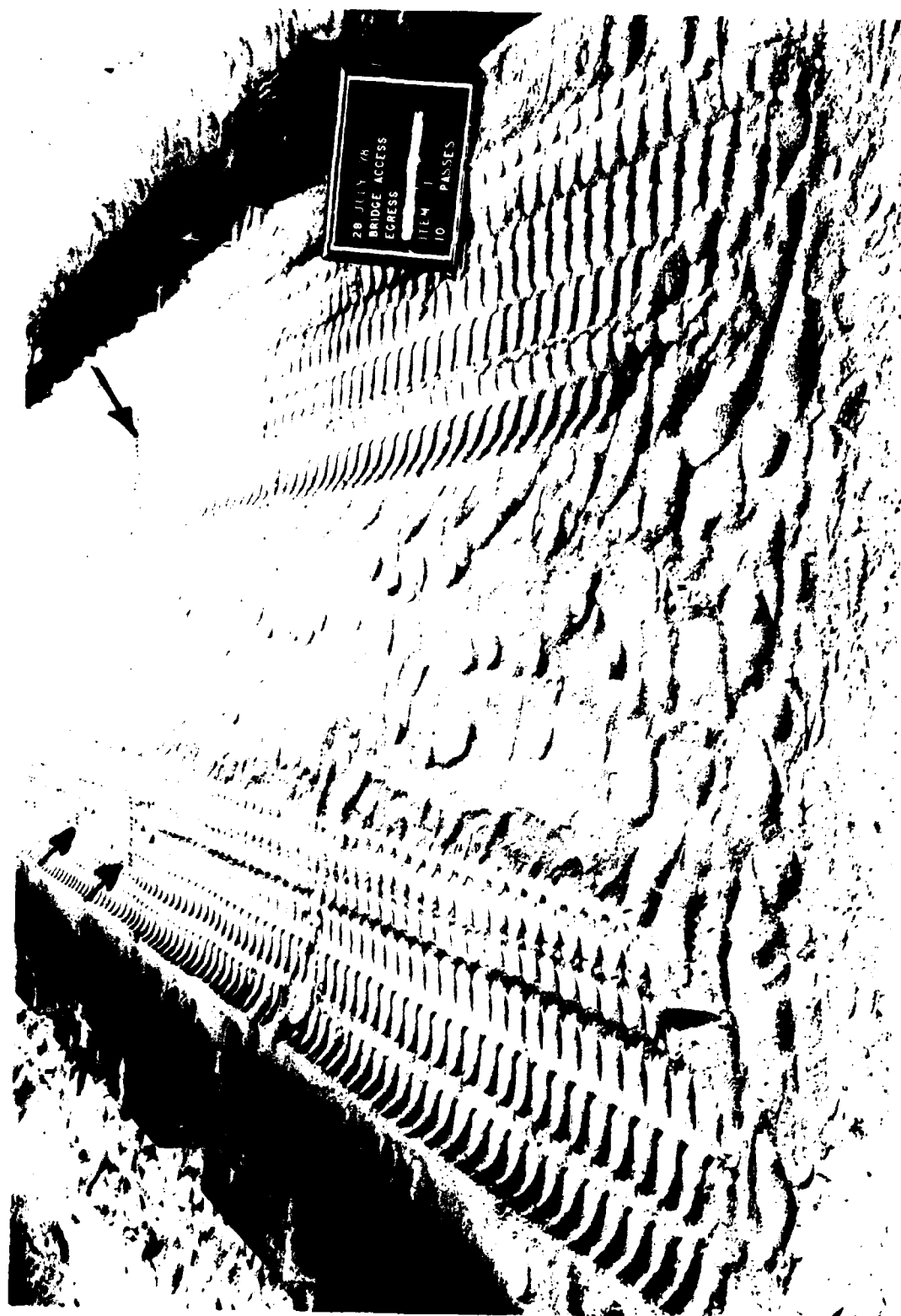
PROFILE - ITEM 1 - RIGHT WHEEL PATH
 BORDEN FIBERGLASS PANELS



Panels replaced, overfilled with 2-in. sand layer and weights on ends of panels

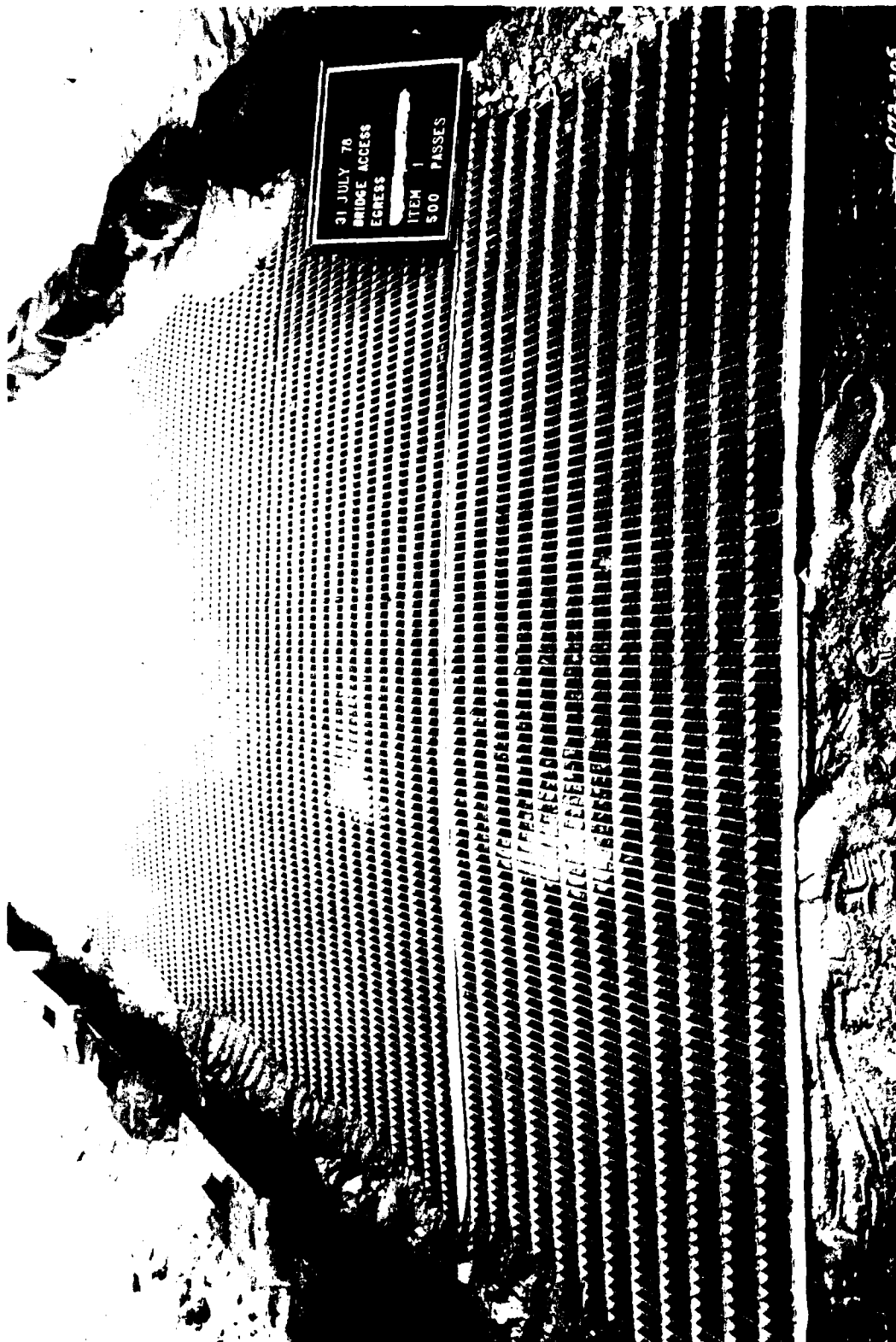
Incl 28.

343

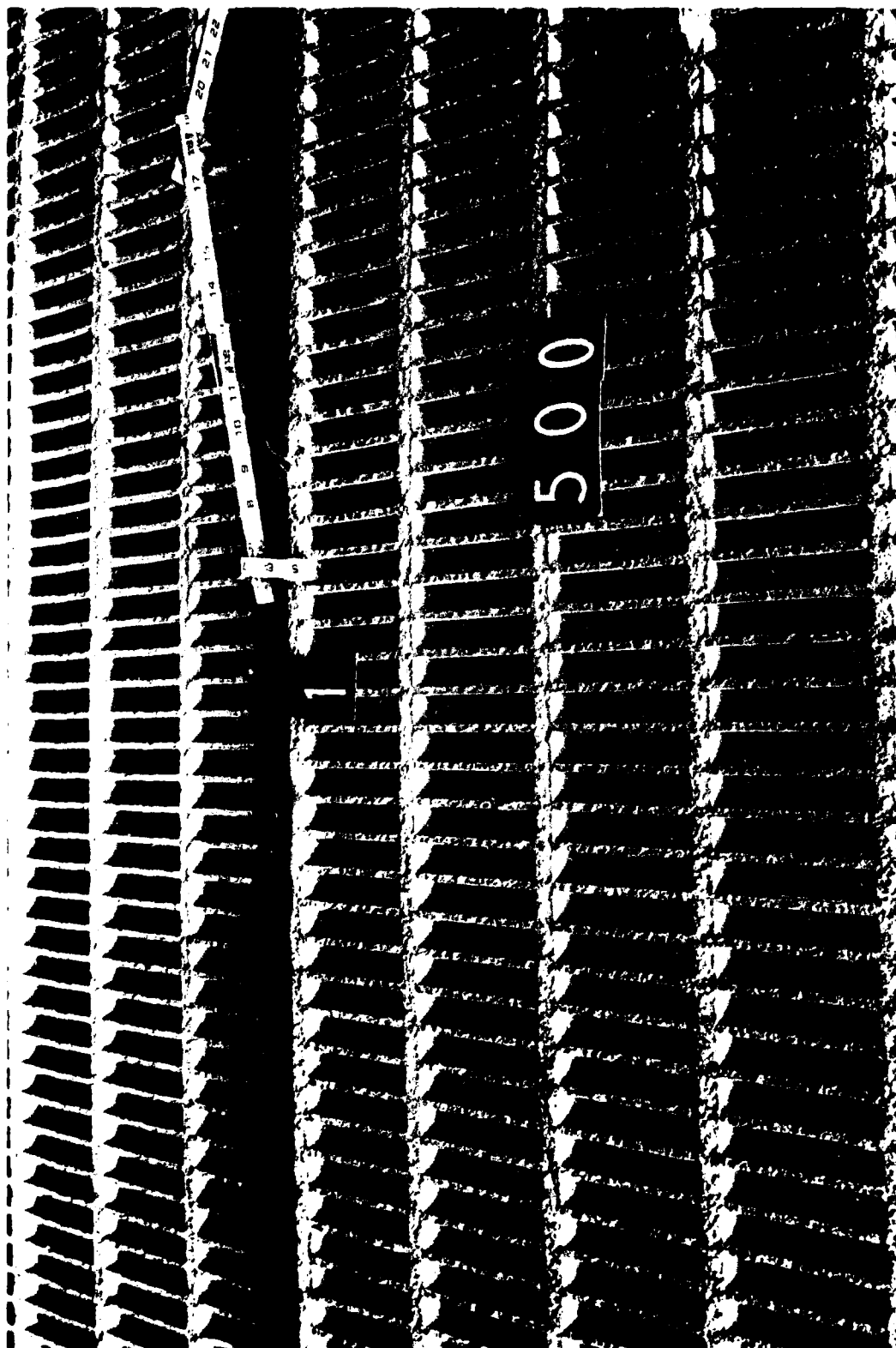


Item 1 after 10 passes (reconstructed)

Incl 29.



Item 1 after 500 passes (reconstructed)



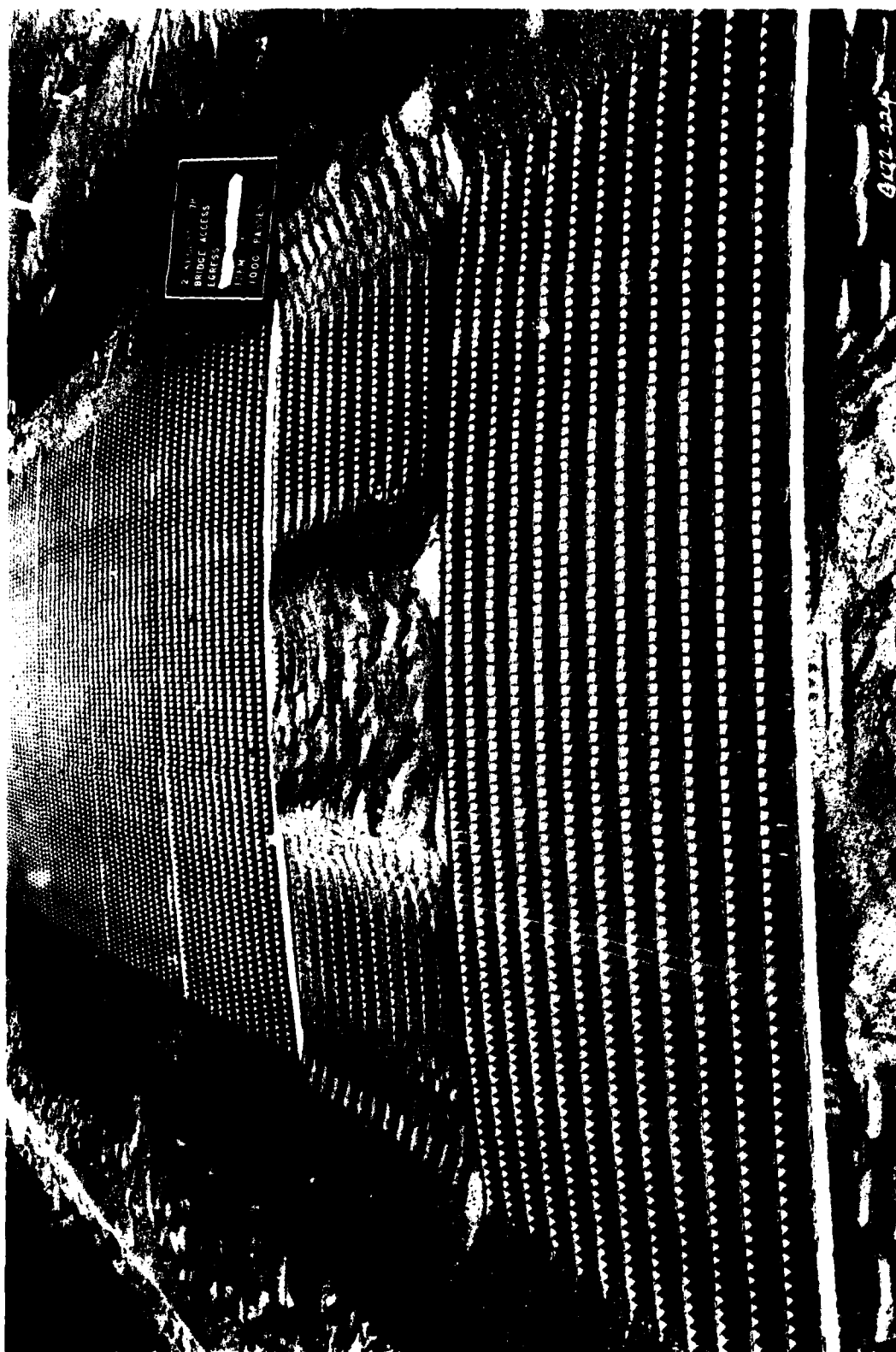
Panel in item 1 after 500 passes, bridging of subgrade



Items 1 and 2 at 500 passes (panels overfilled with sand)

Incl 32.

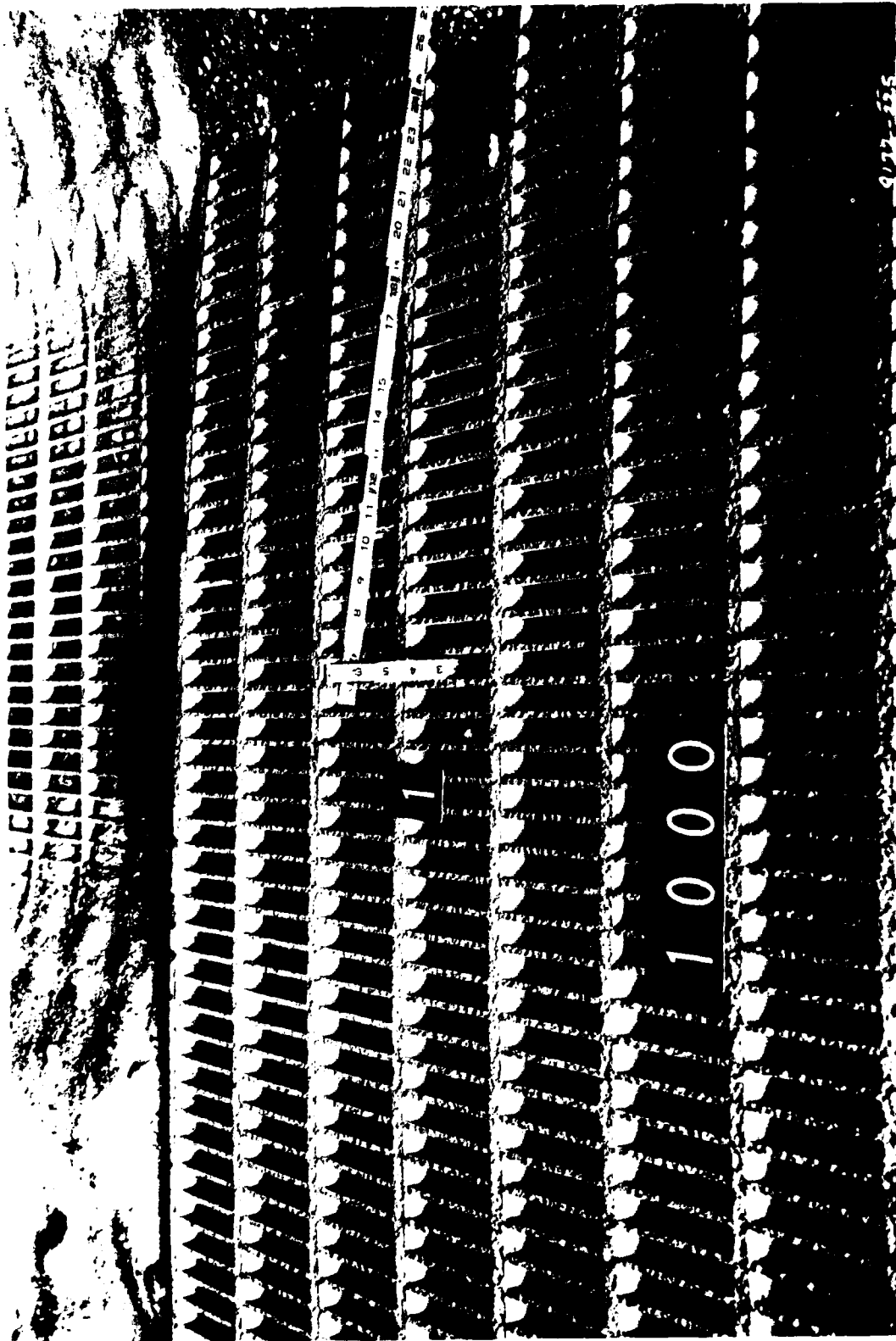
347



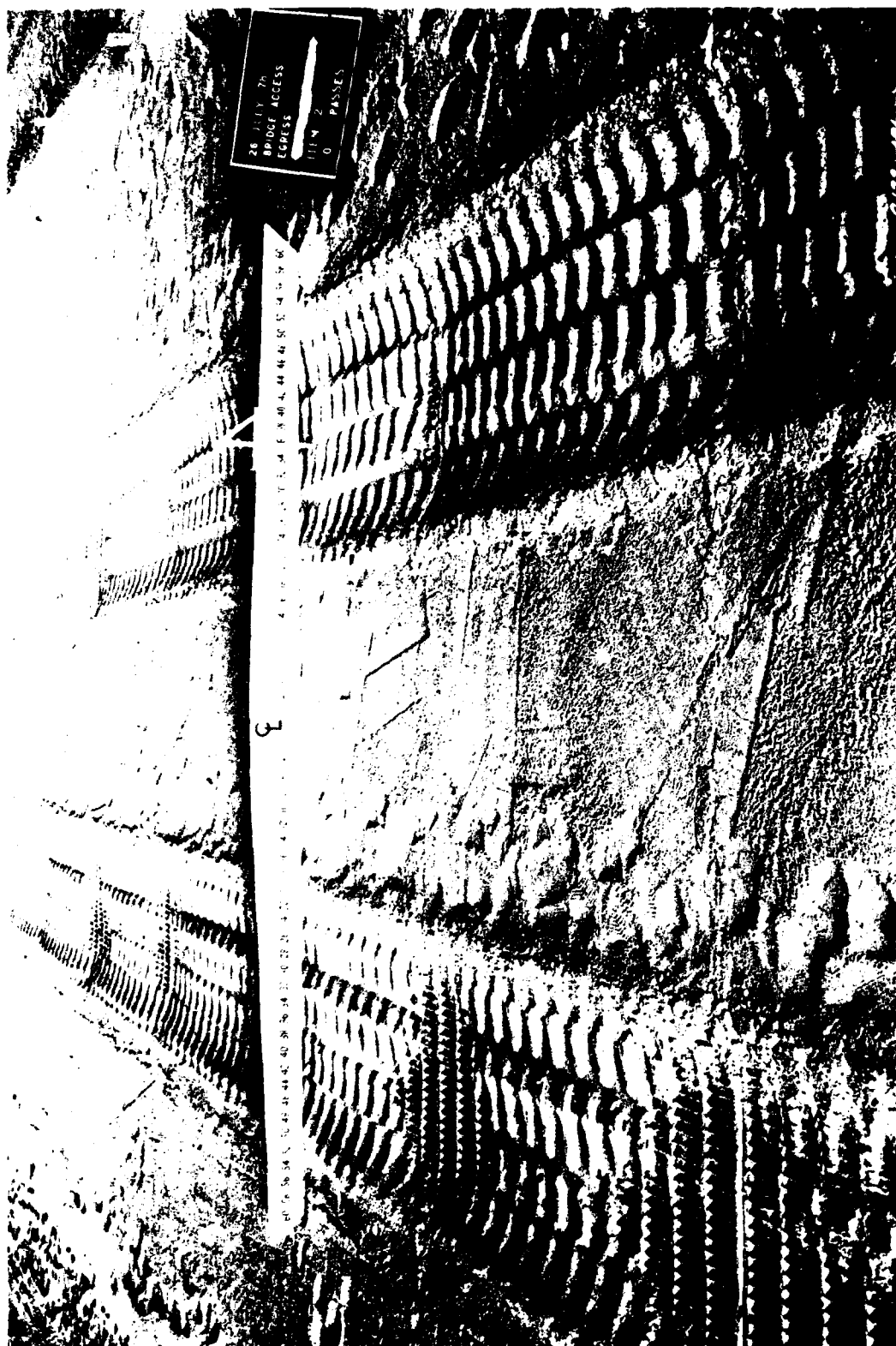
Item 1 after 1000 passes

Incl. 33.

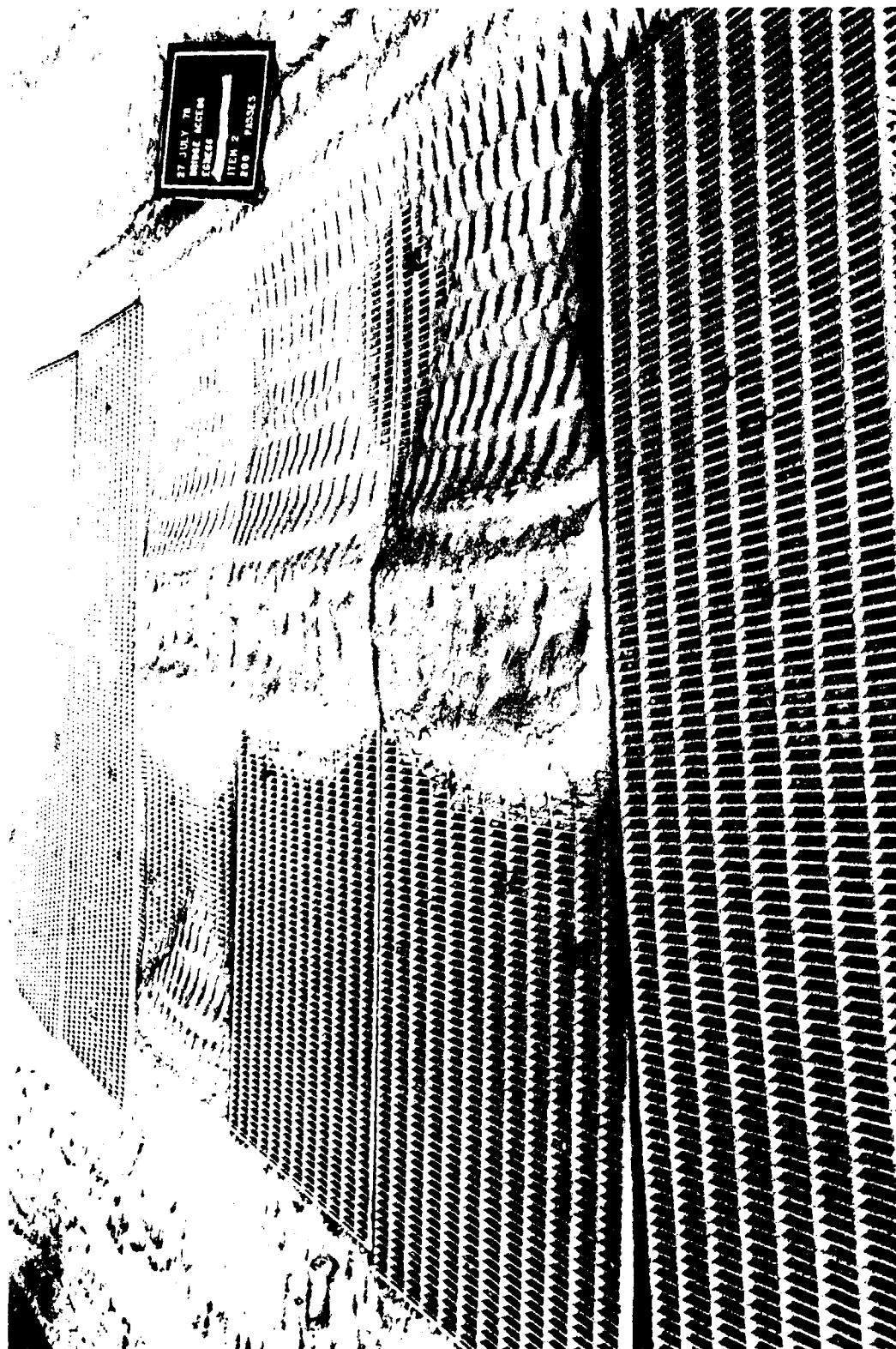
348



Panels in Item 1 after 1000 passes, bridging of subgrade



Item 2 after 10 passes of traffic

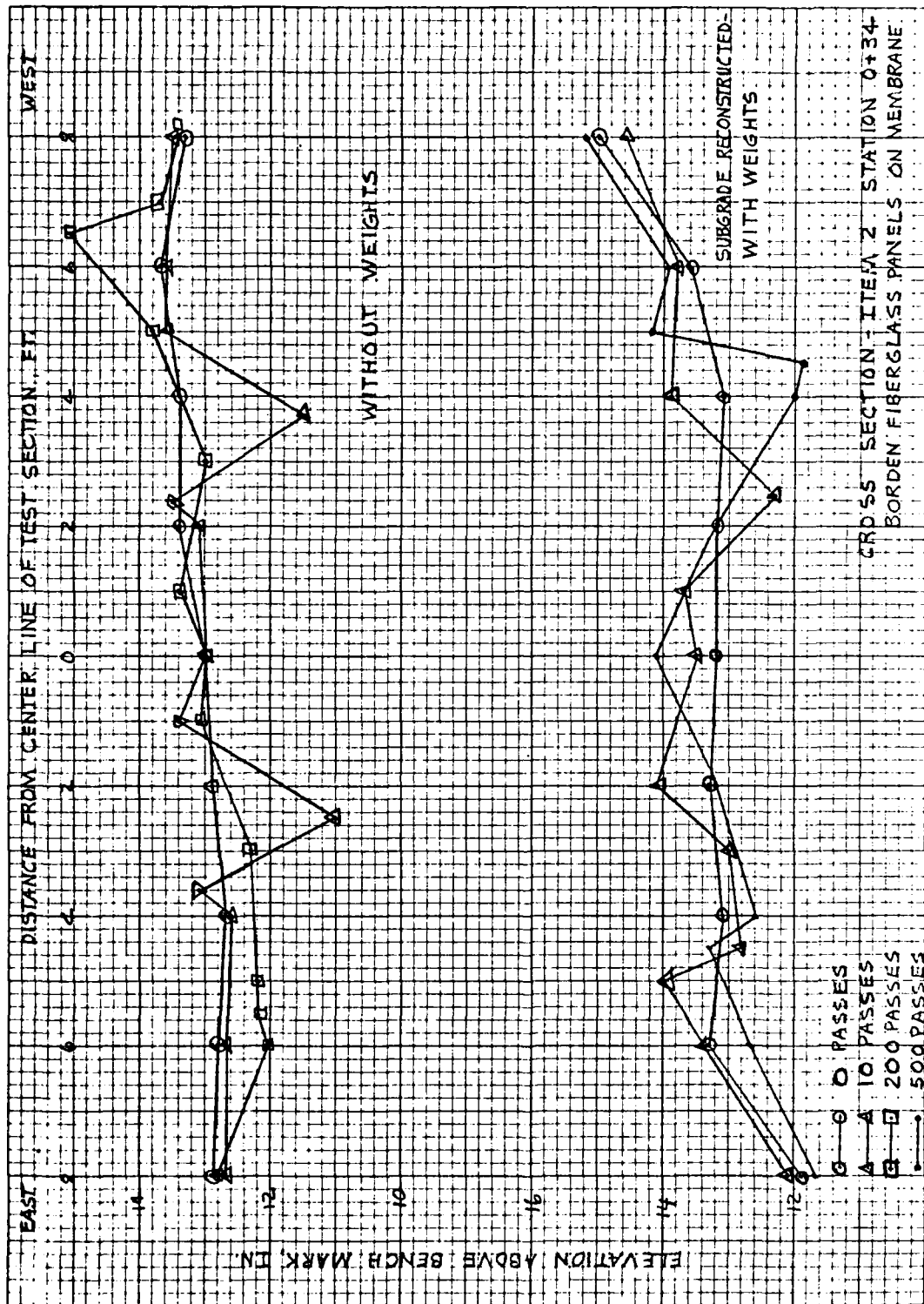


27 JULY 78
MILWAUKEE
ECHOES
ITEM 2
200 PAGES

Item 2 after 200 pages of traffic

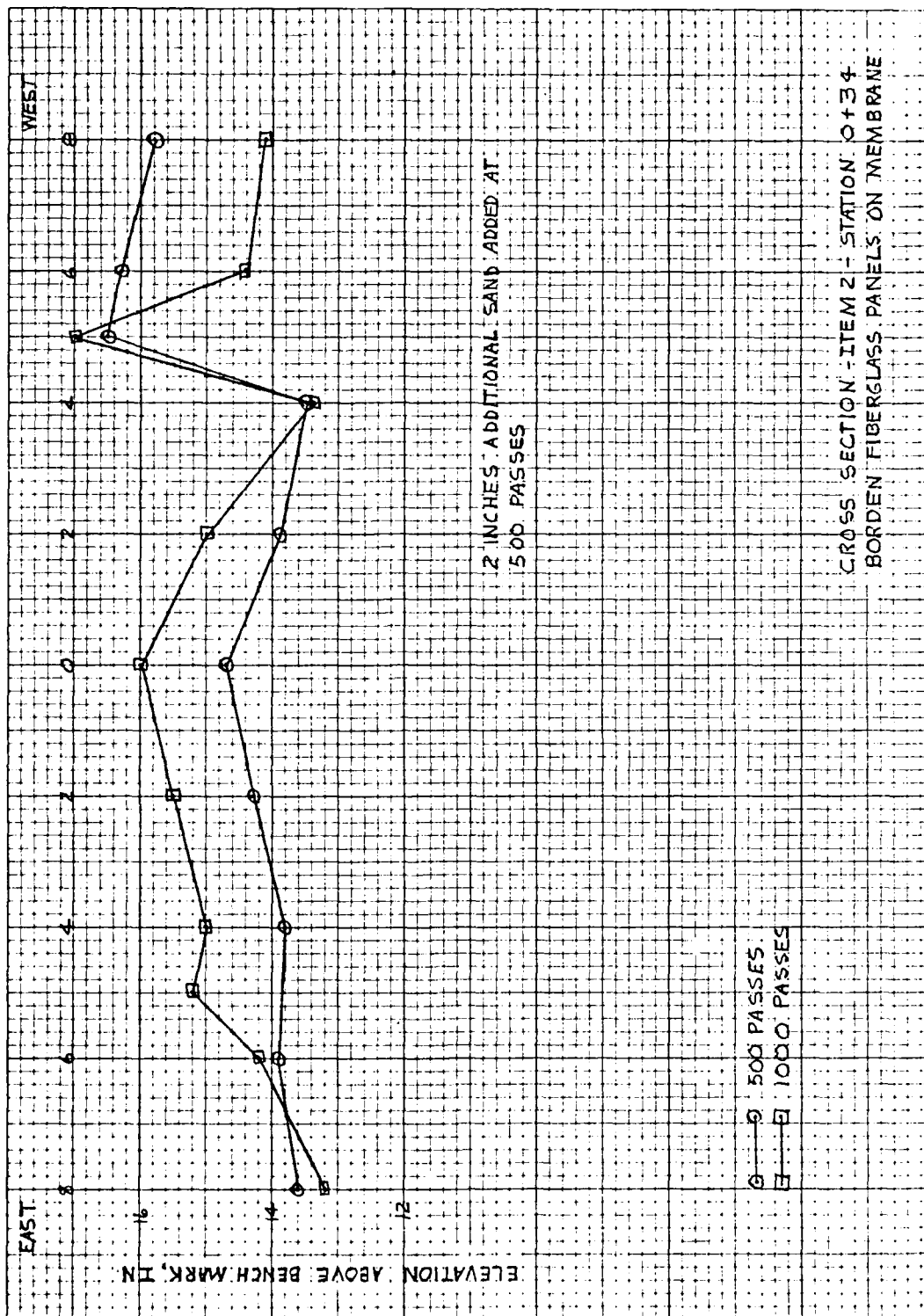
Incl 30.

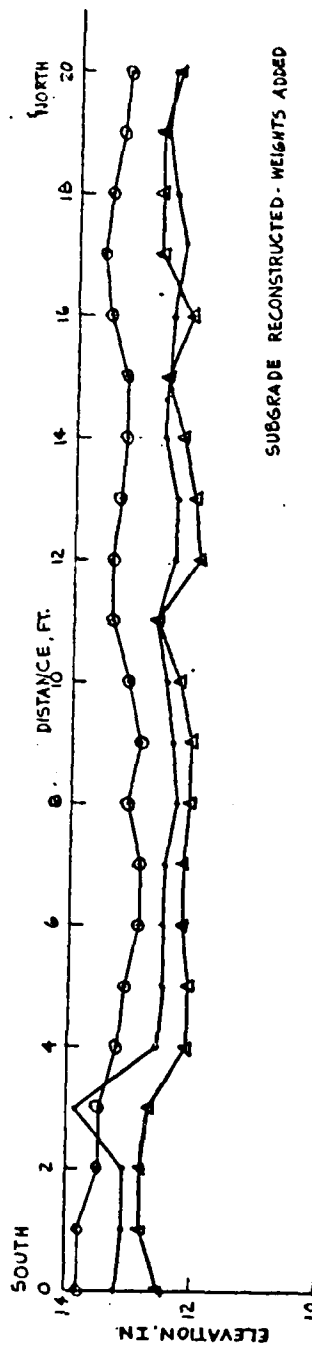
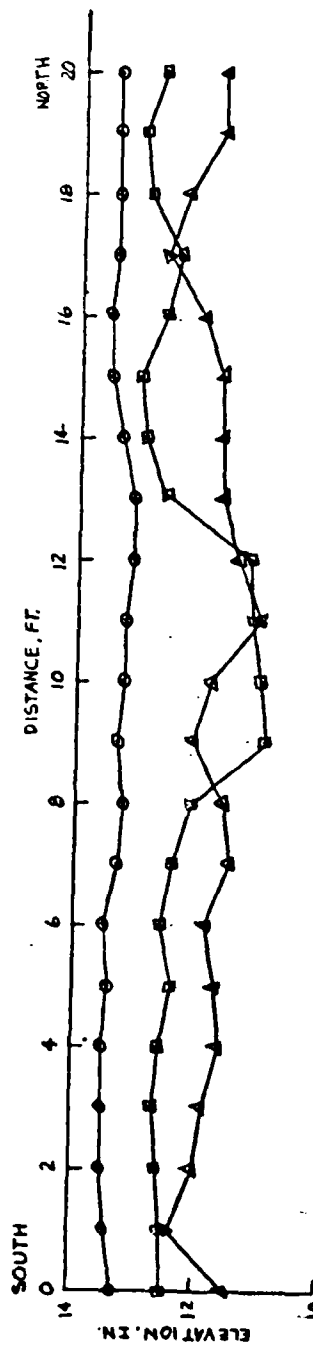
351



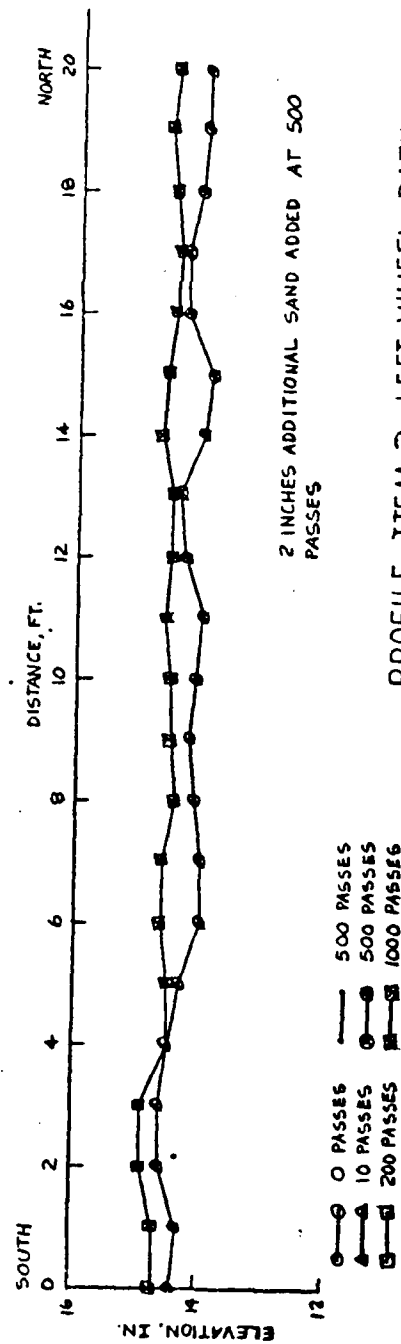
INCL 37 PAGE 1

INCL 37 PAGE 2



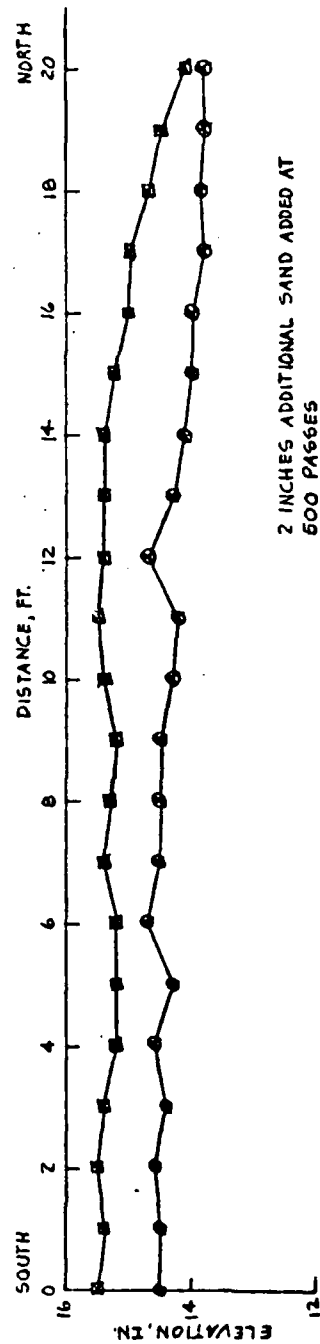
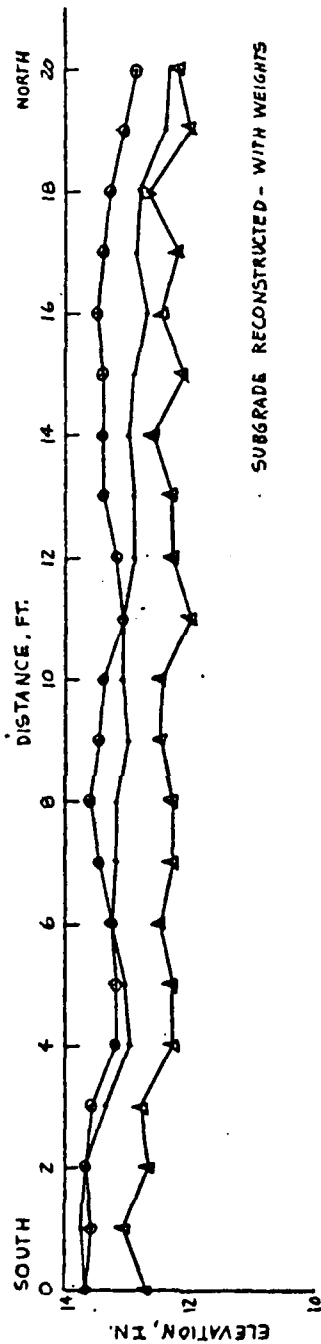
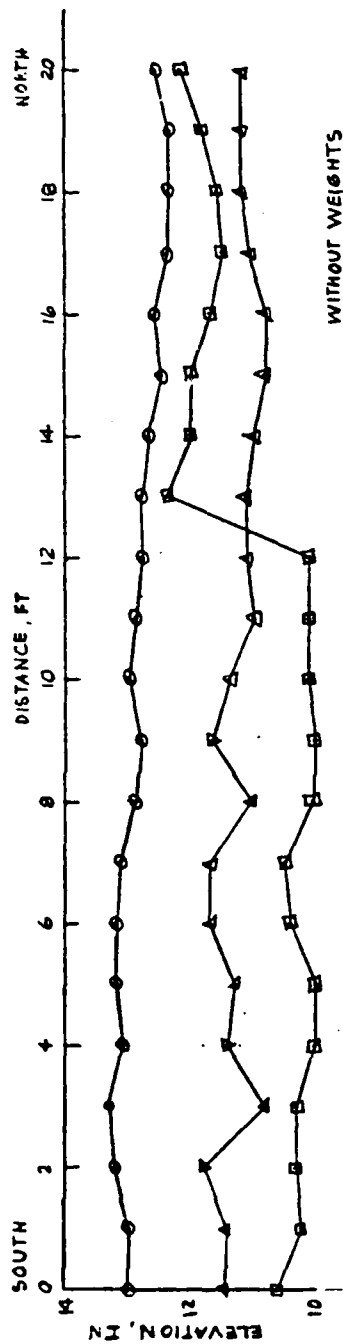


SUBGRADE RECONSTRUCTED - WEIGHTS ADDED



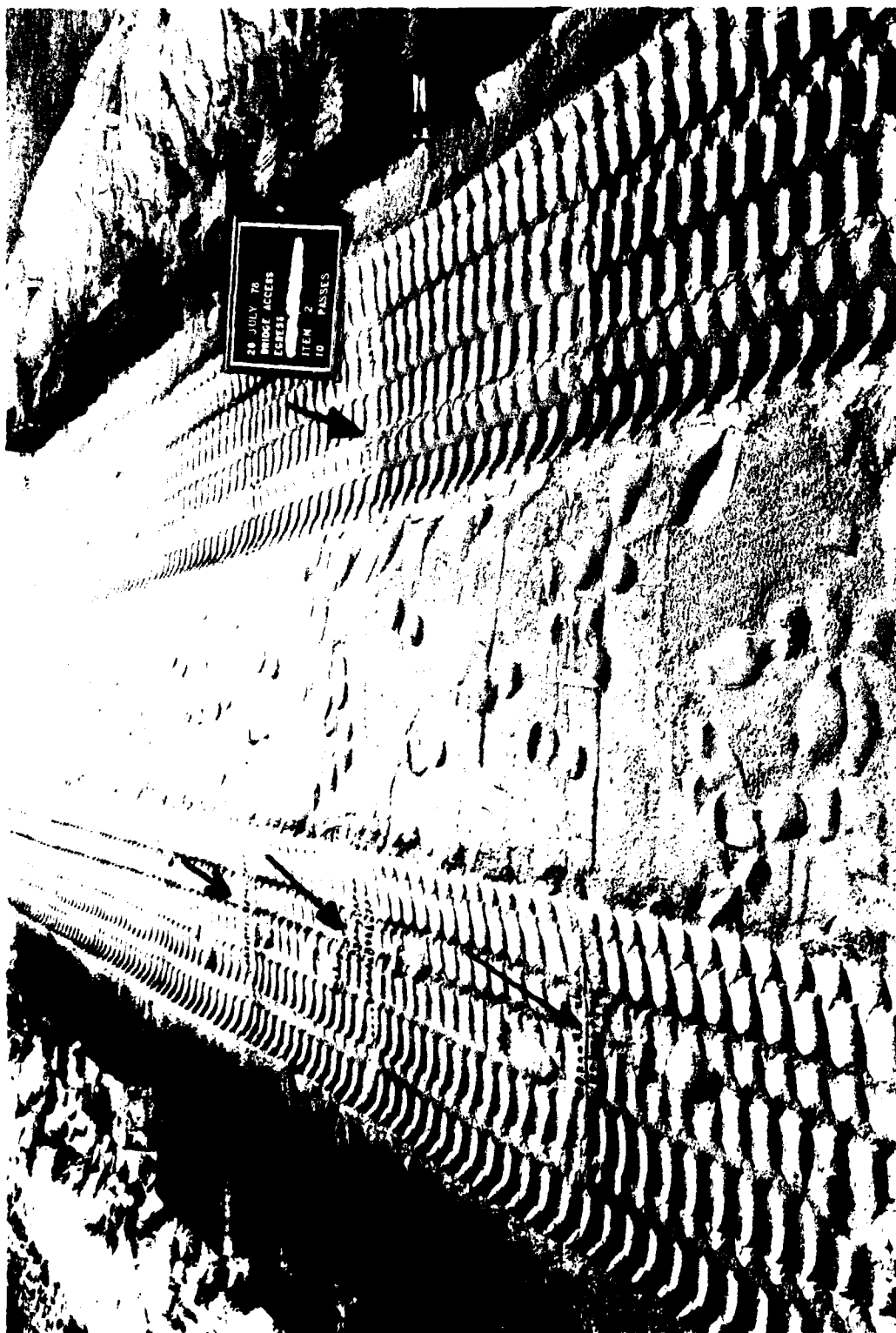
2 INCHES ADDITIONAL SAND ADDED AT 500 PASSES

PROFILE - ITEM 2 - LEFT WHEEL PATH
BORDEN FIBERGLASS PANELS ON MEMBRANE

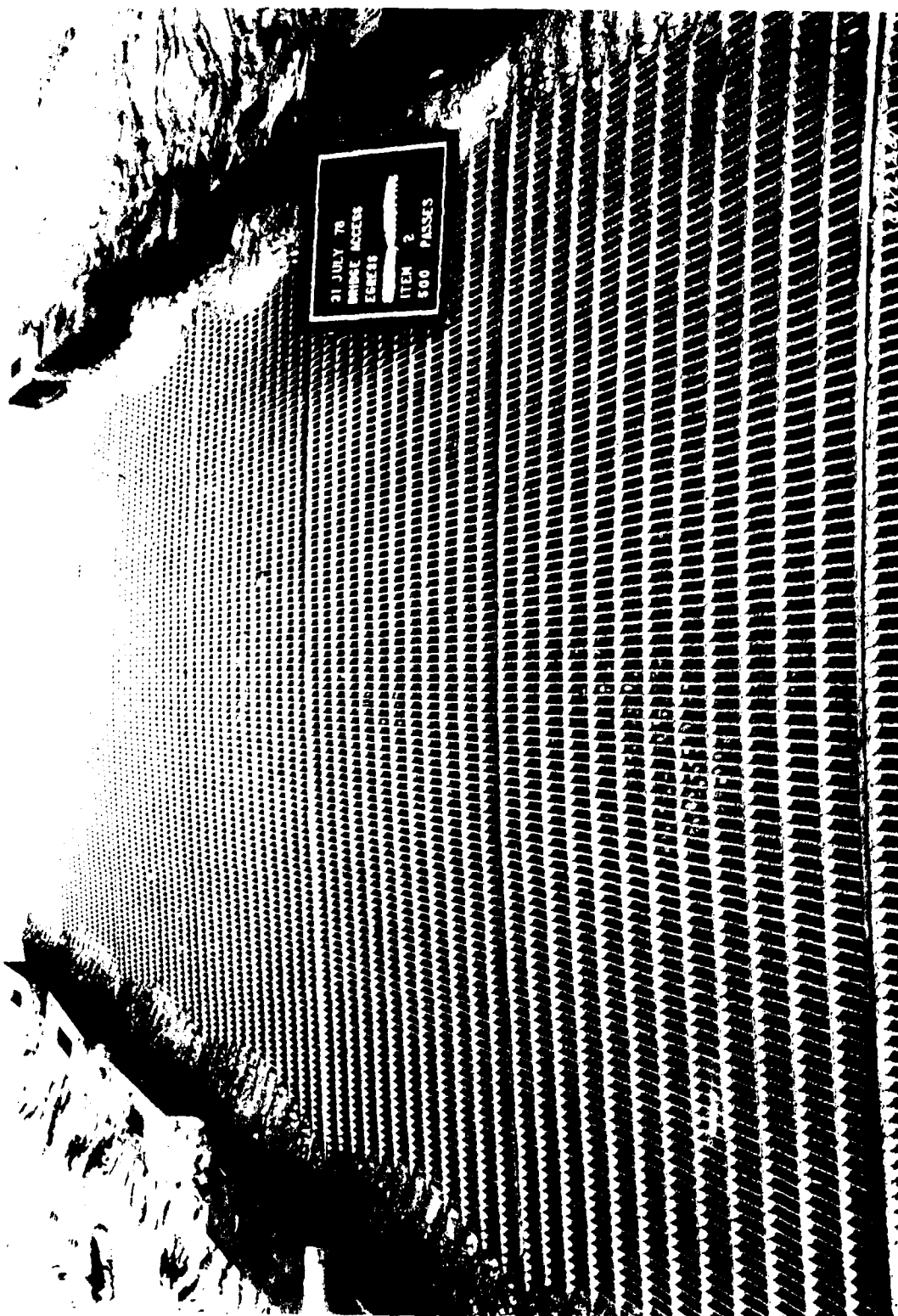


PROFILE- ITEM 2 - RIGHT WHEEL PATH
BORDEN FIBERGLASS PANELS ON MEMBRANE

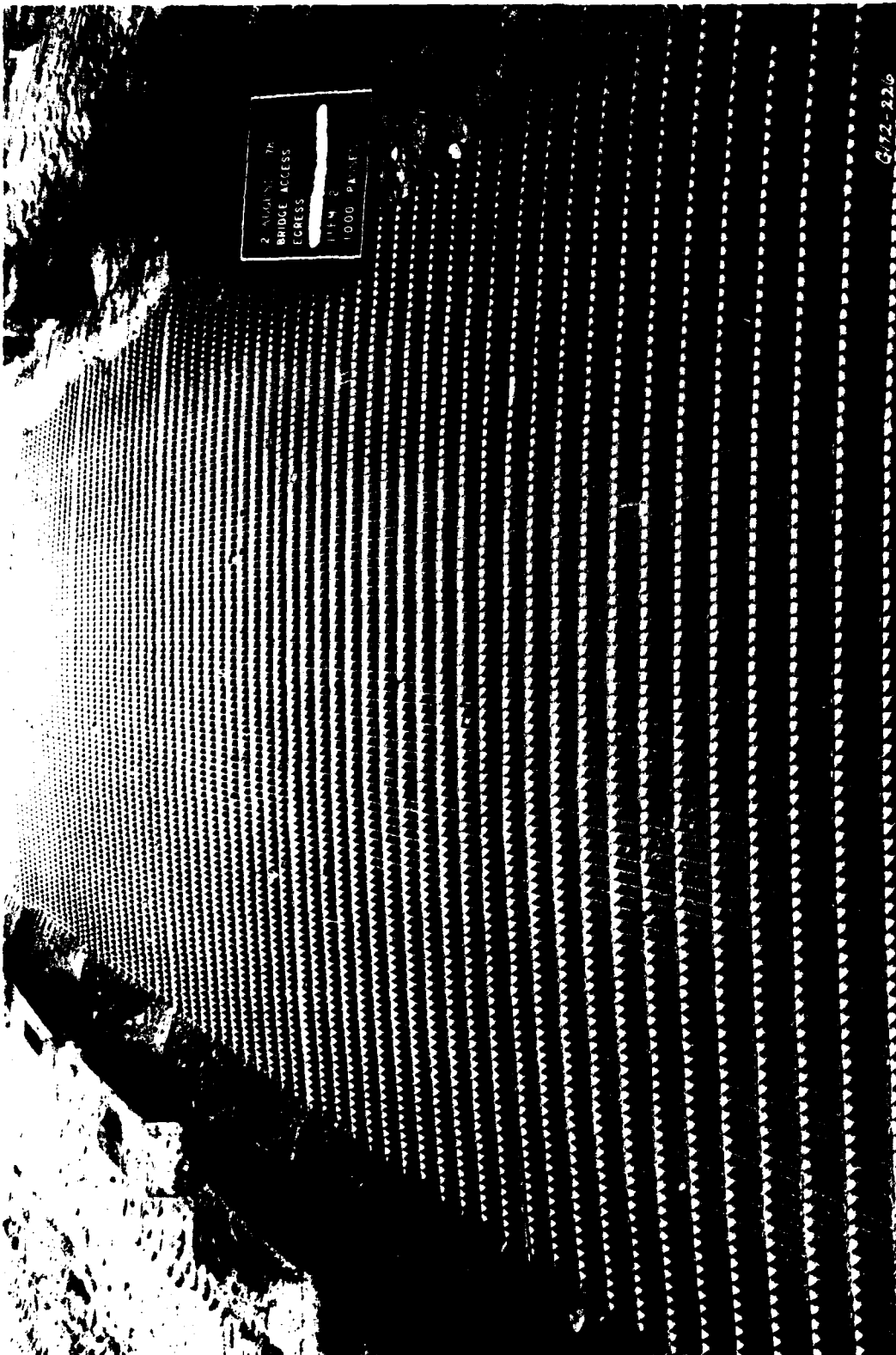
0 PASSES 500 PASSES
10 PASSES 500 PASSES
200 PASSES 1000 PASSES



Item 2 after 10 passes (reconstructed)



Item 2, July 78, 500 passes (presented)



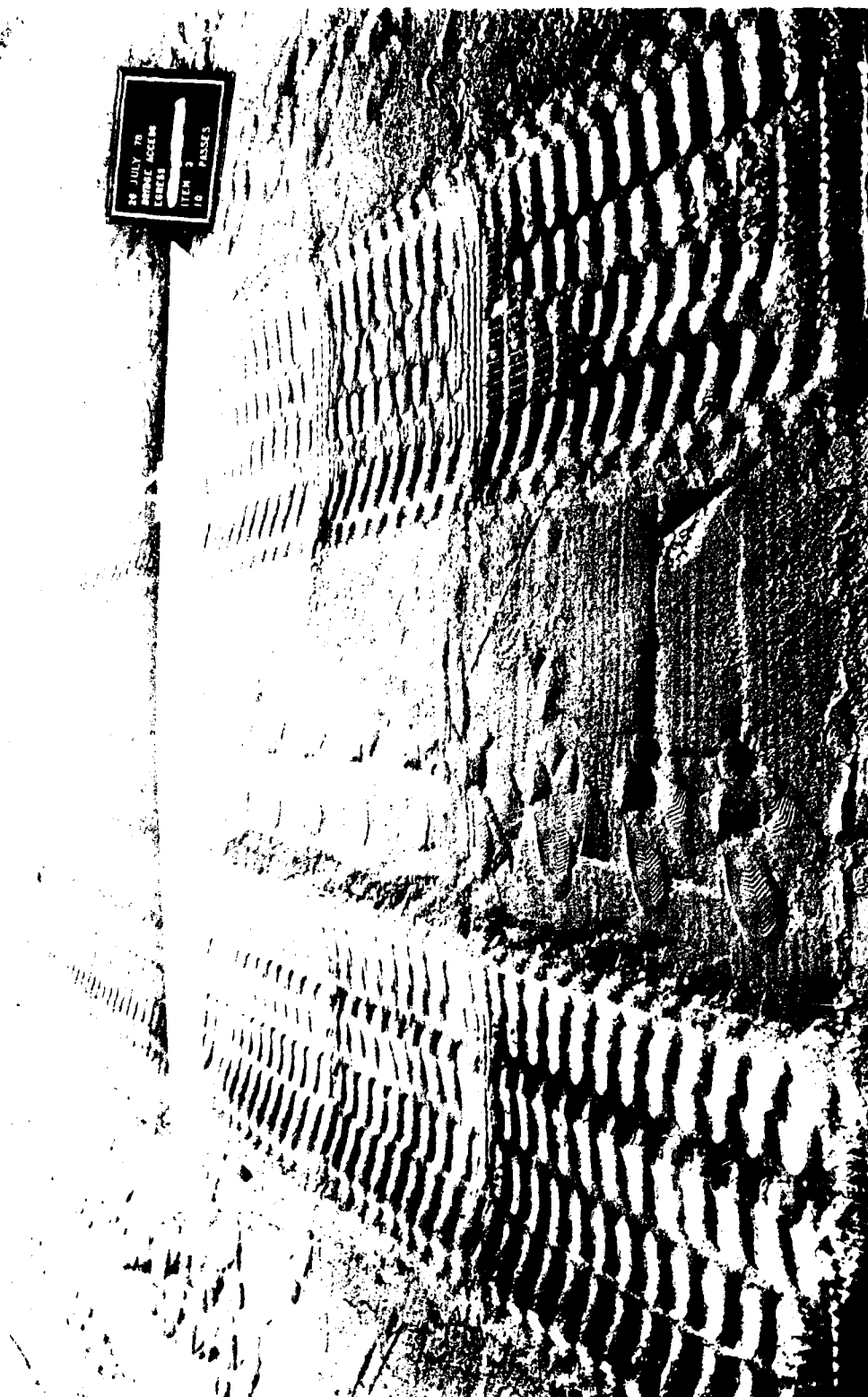
G/12-226

Item 2 after 1000 passes of traffic

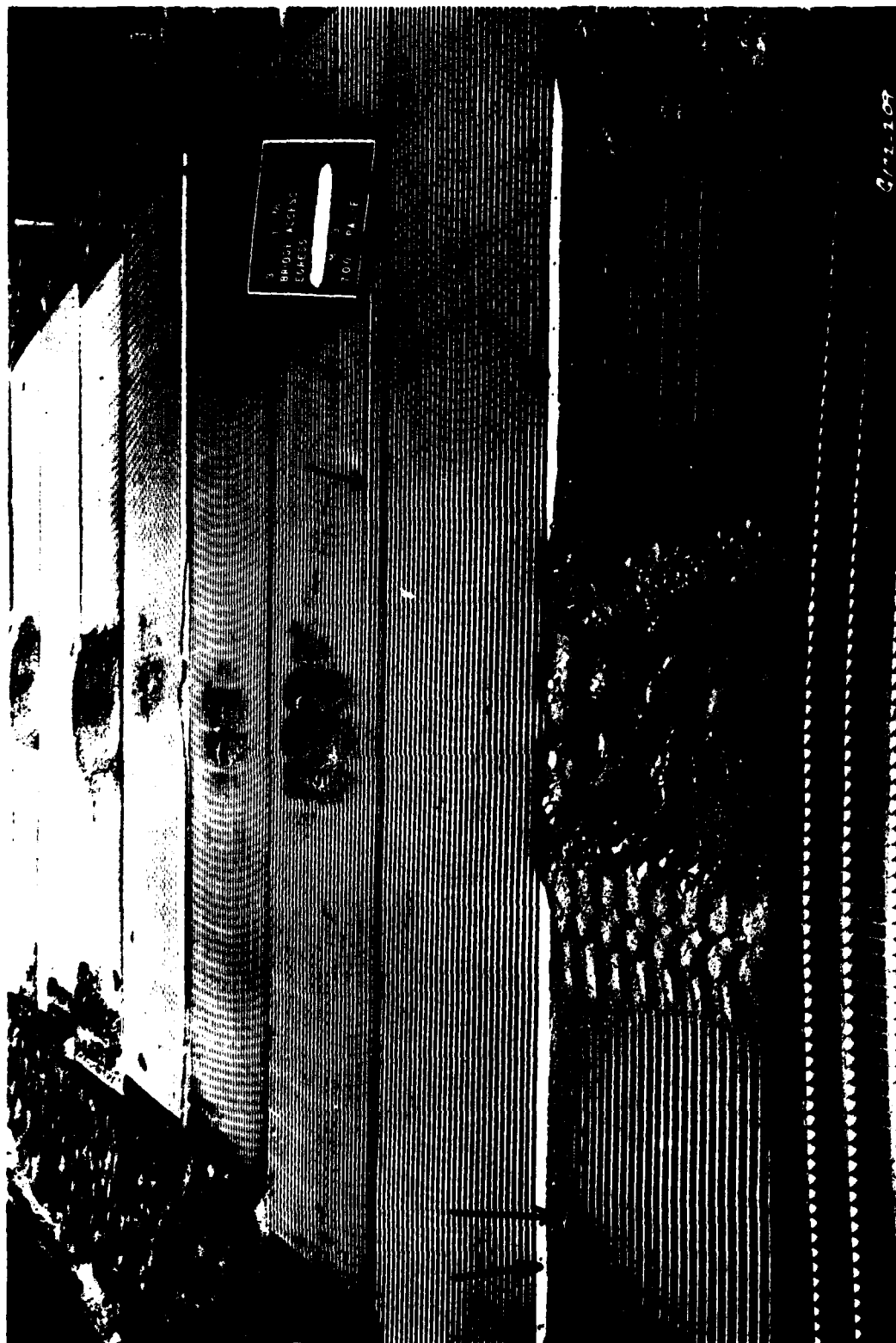
Incl 41.

358

20 JULY 70
BRIDGE AREA
EGRESS
ITEM 3
10 PASSES



Item 3 after 10 passes of traffic

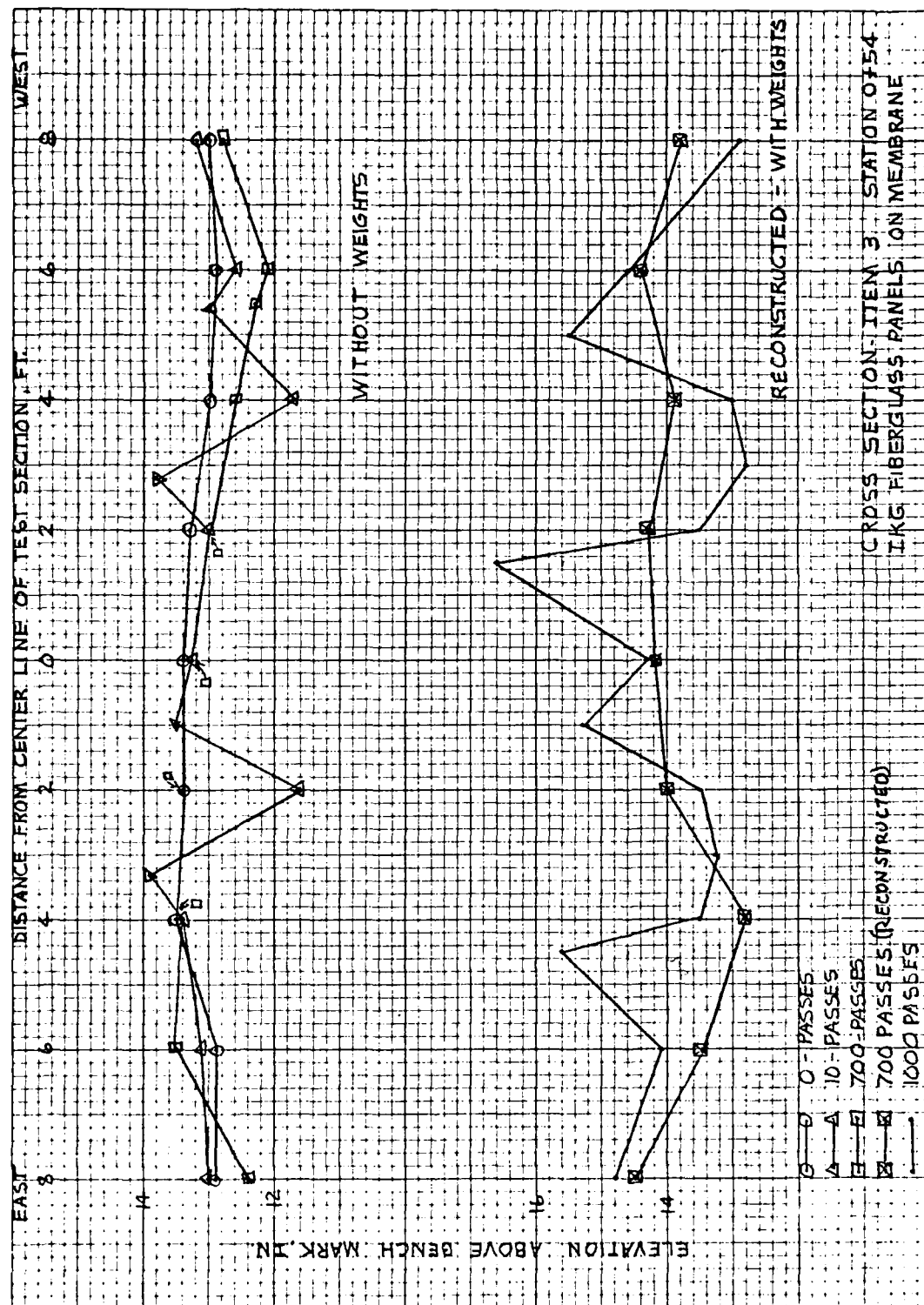


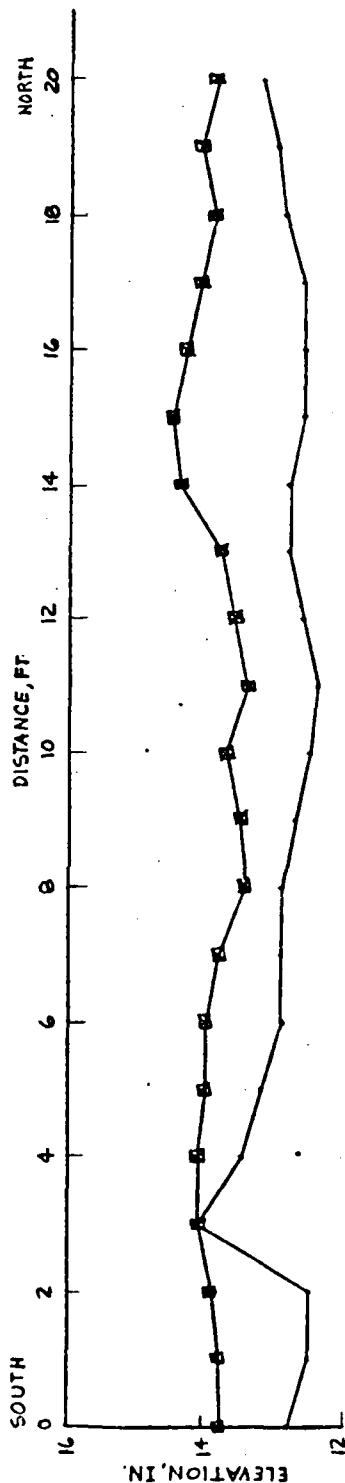
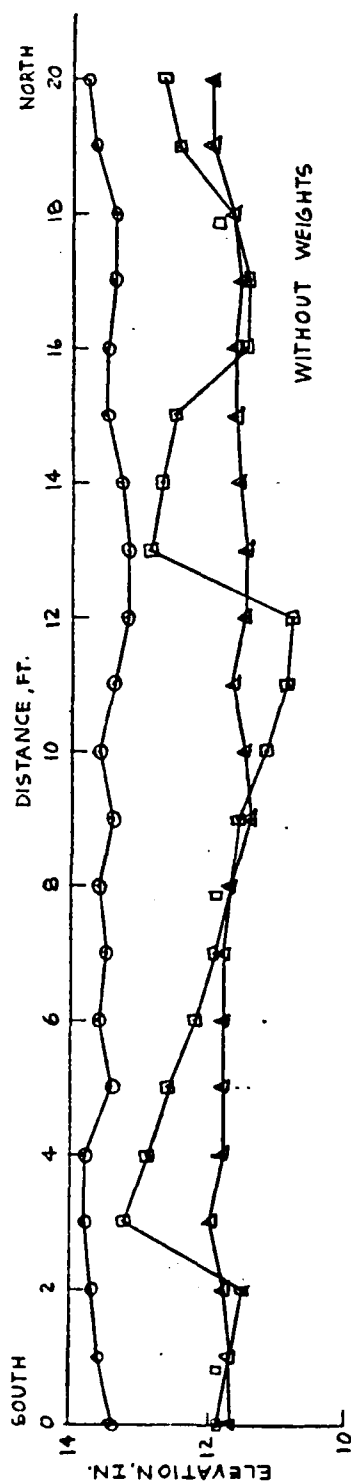
012.107

Item 3 after 700 passes of traffic

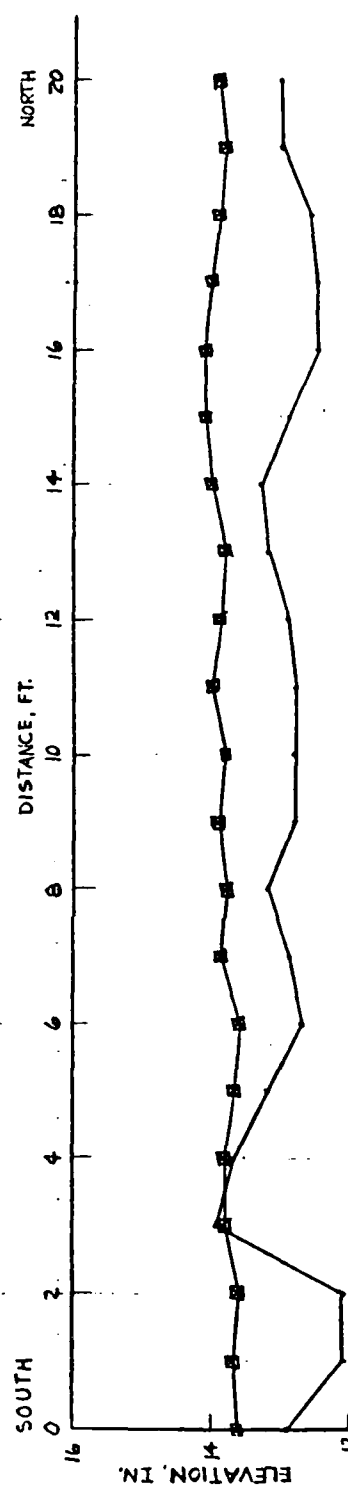
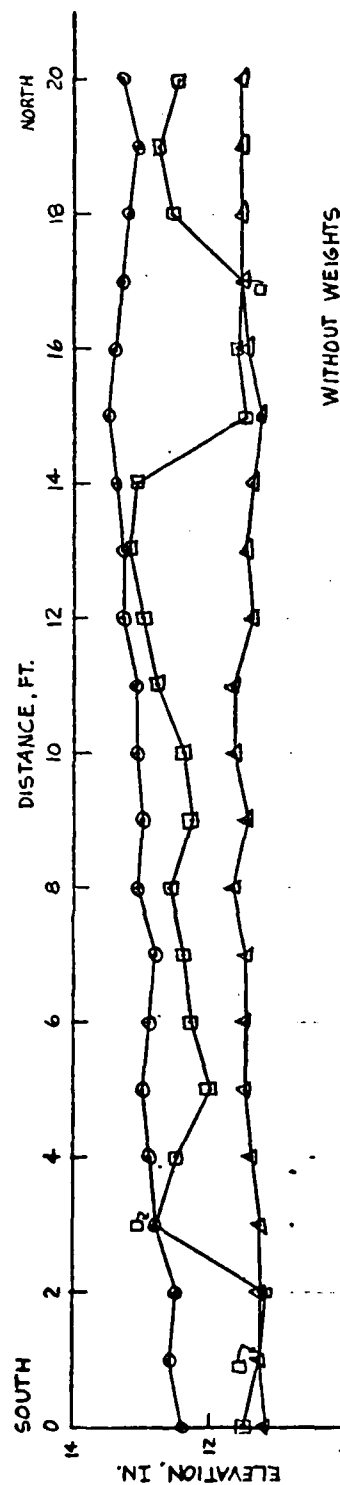
Incl 43.

INCL 44





PROFILE-ITEM 3- LEFT WHEEL PATH
IKG FIBERGLASS PANELS ON MEMBRANE



PROFILE-ITEM 3-RIGHT WHEEL PATH
IKG FIBERGLASS PANELS ON MEMBRANE

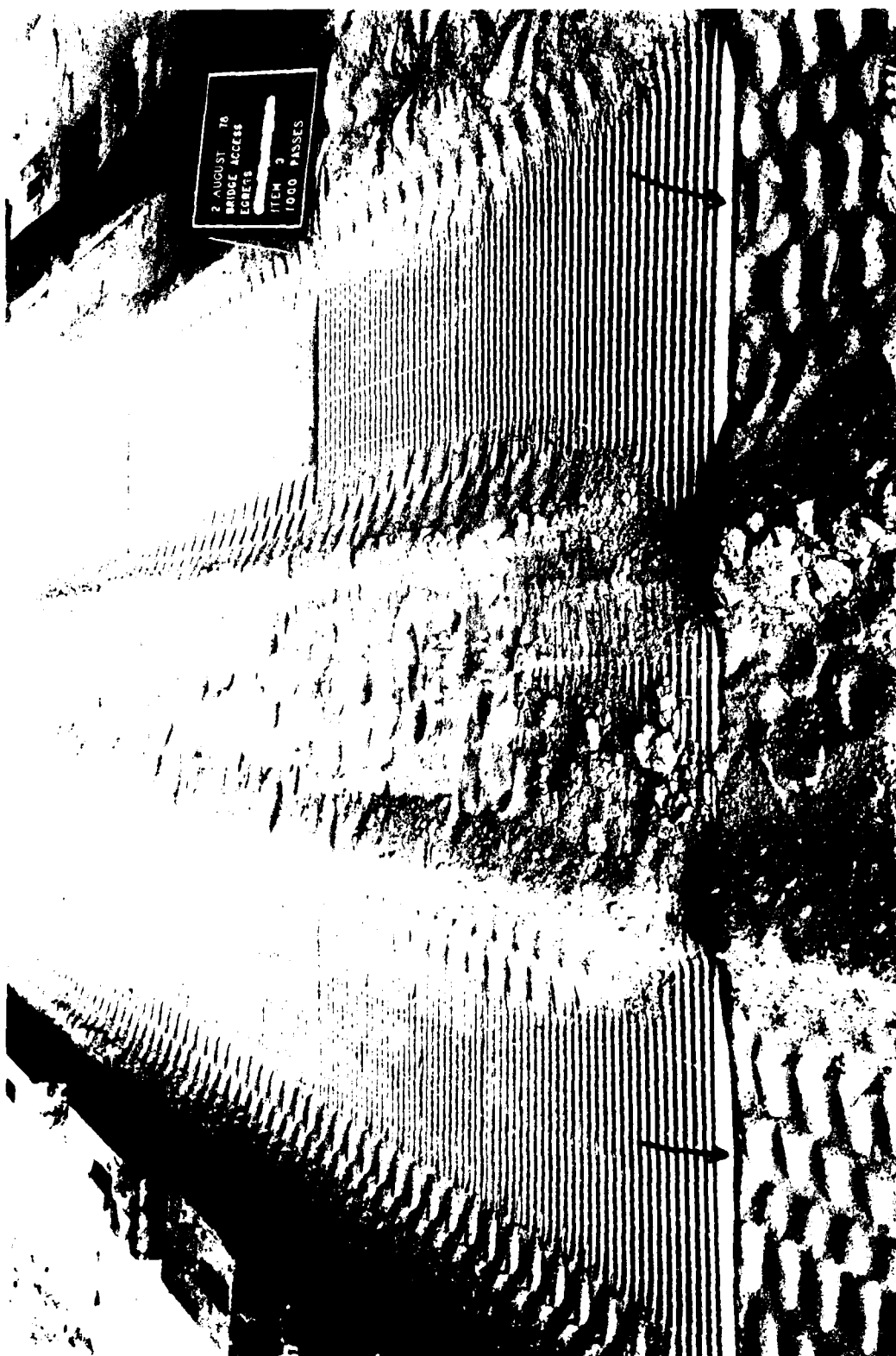


G172-213

Item 3 at 700 passes (reconstructed)

Incl 46.

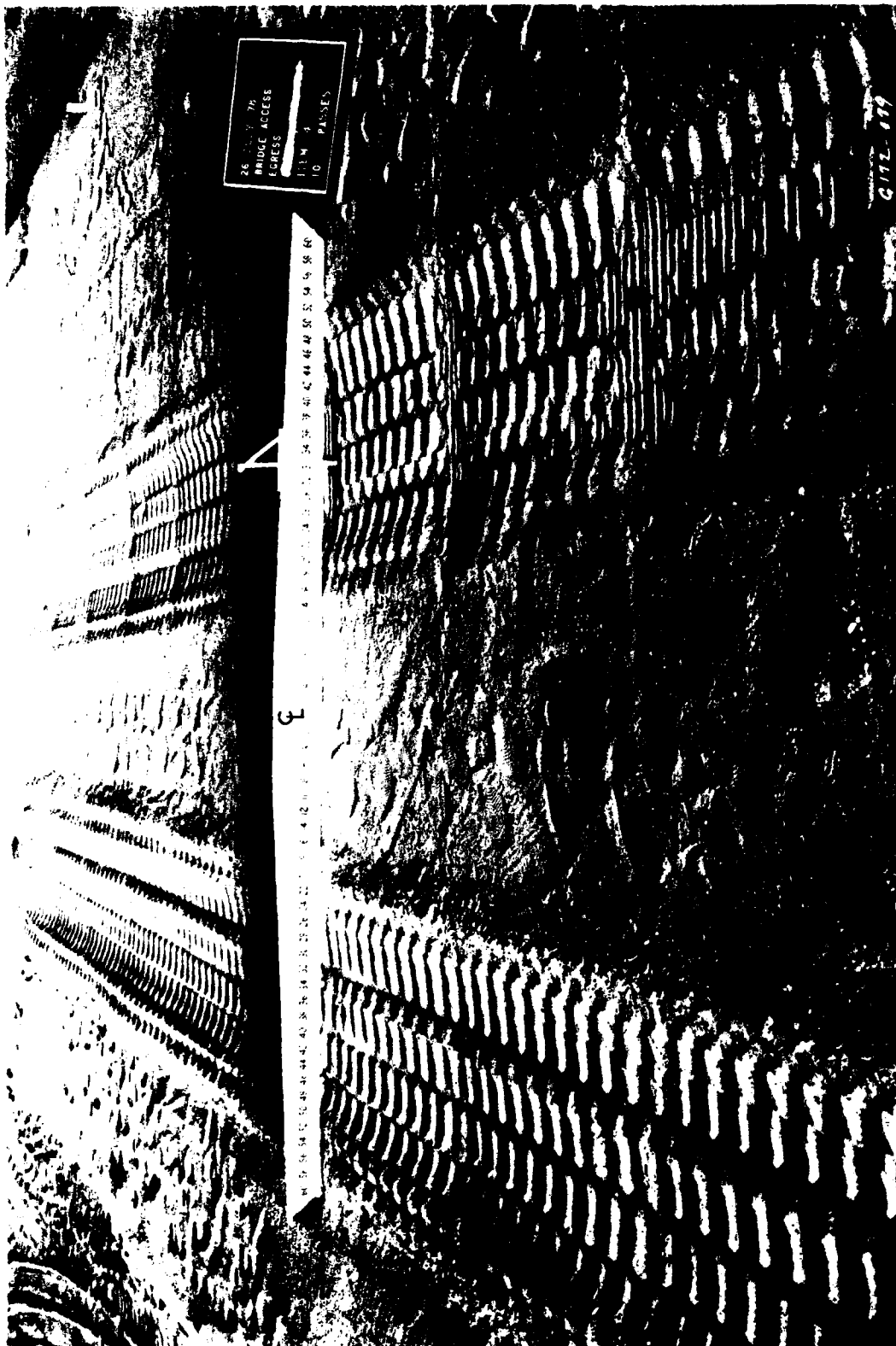
364



Item 3 after 1000 passes of traffic

Incl 47.

365



Item 4 after 10 passes of traffic

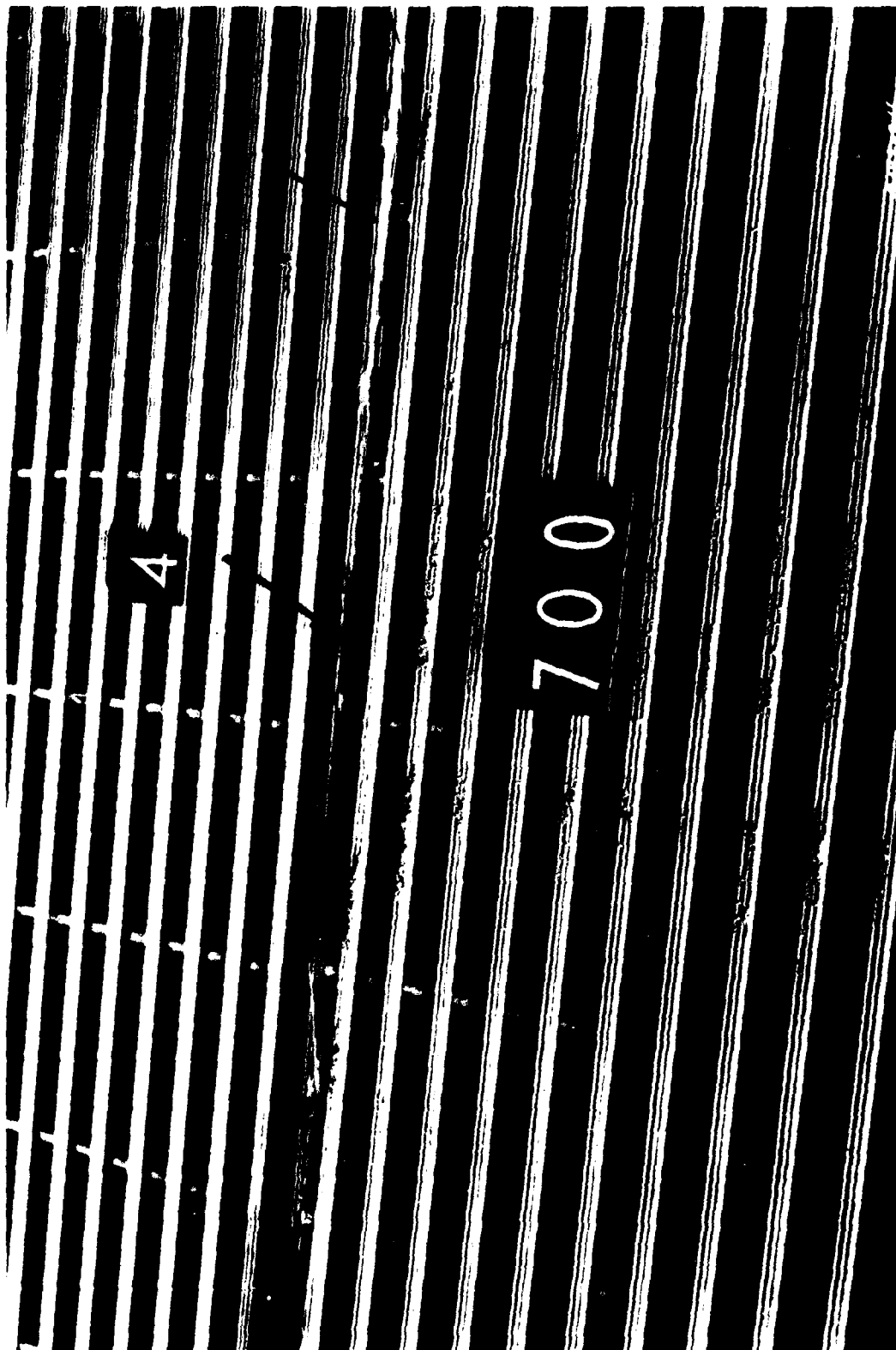
Incl 48.

366



Item 4 after 700 passes of traffic

Incl 49.

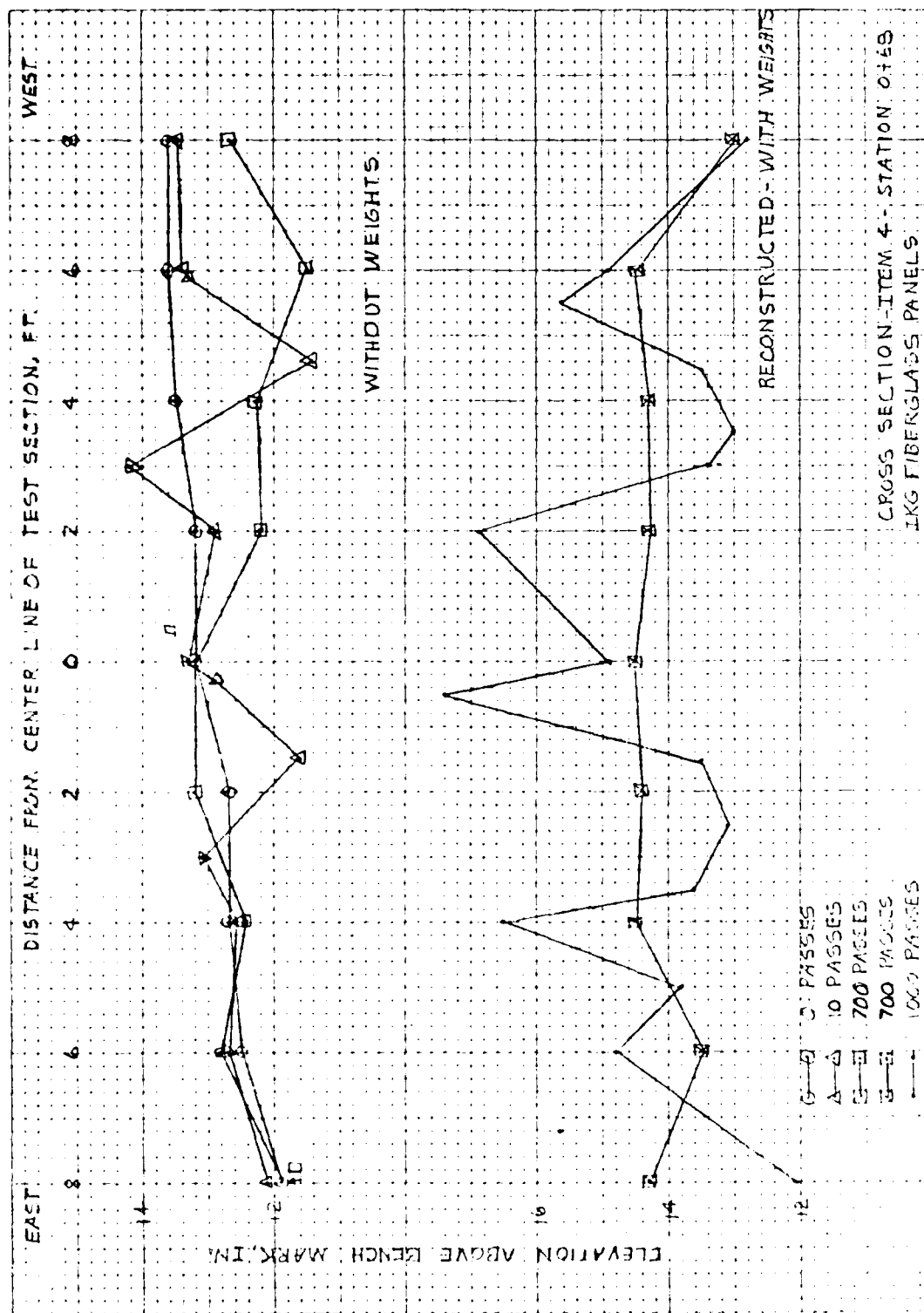


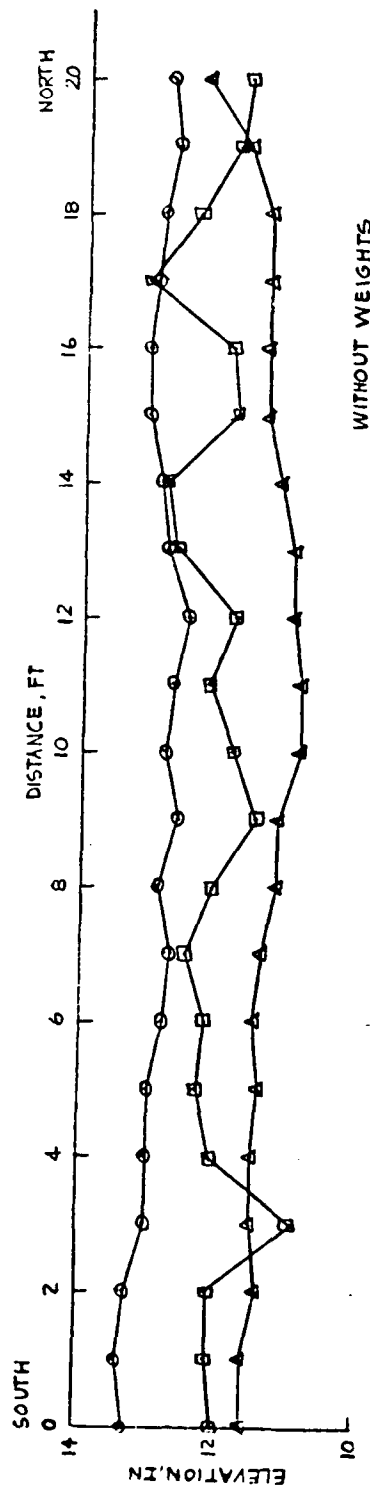
Incl 50.

368

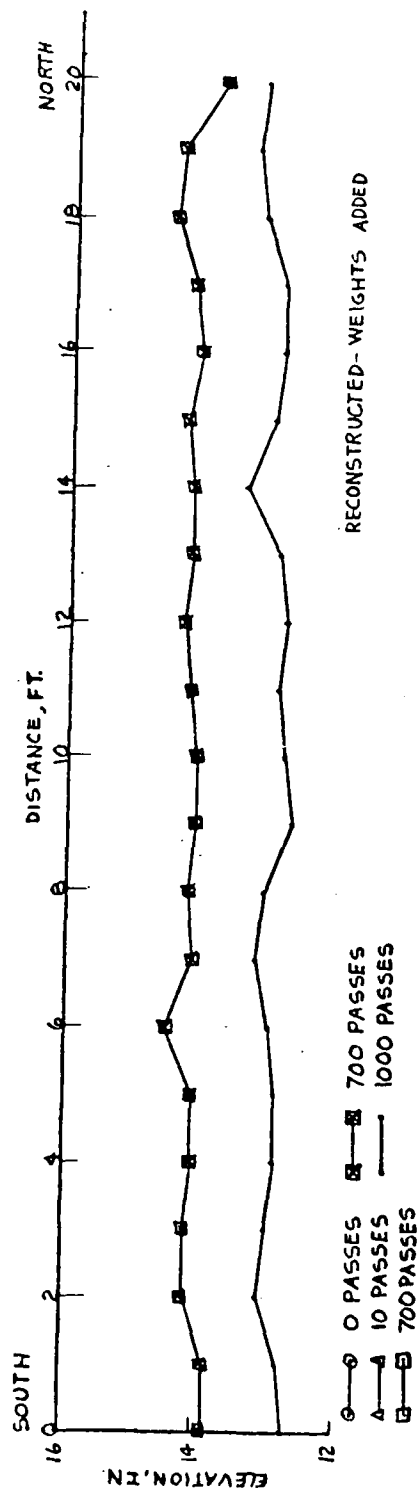
Abrasion on panels in item 4 after 500 passes of traffic

157021



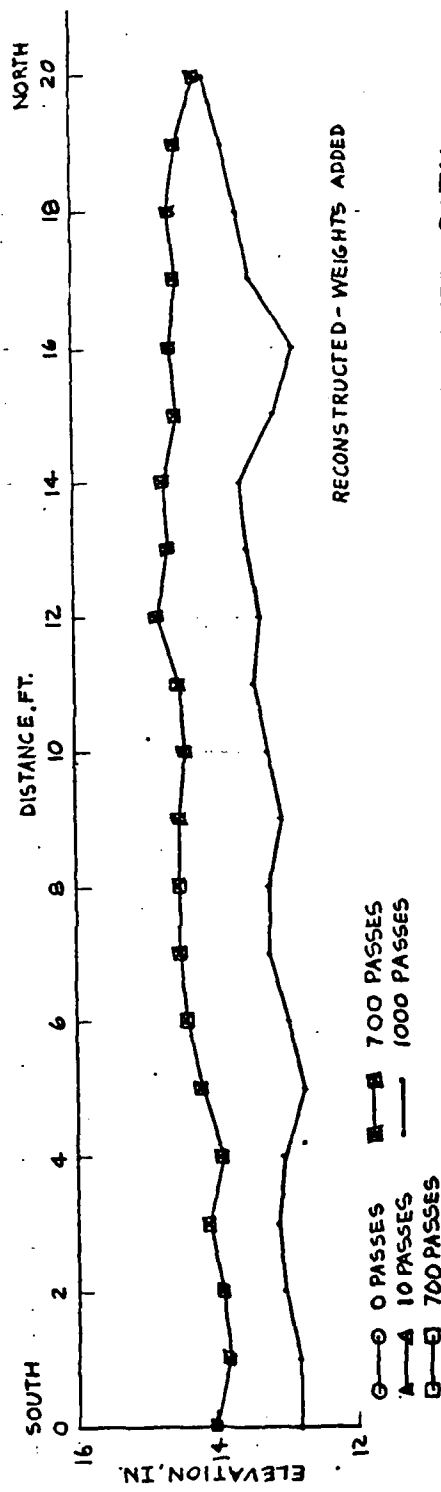
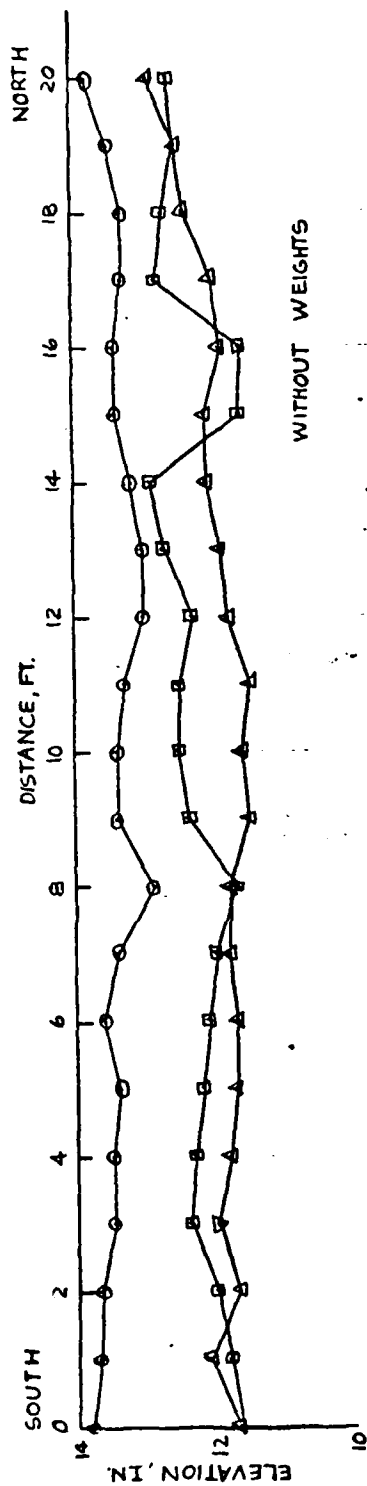


WITHOUT WEIGHTS



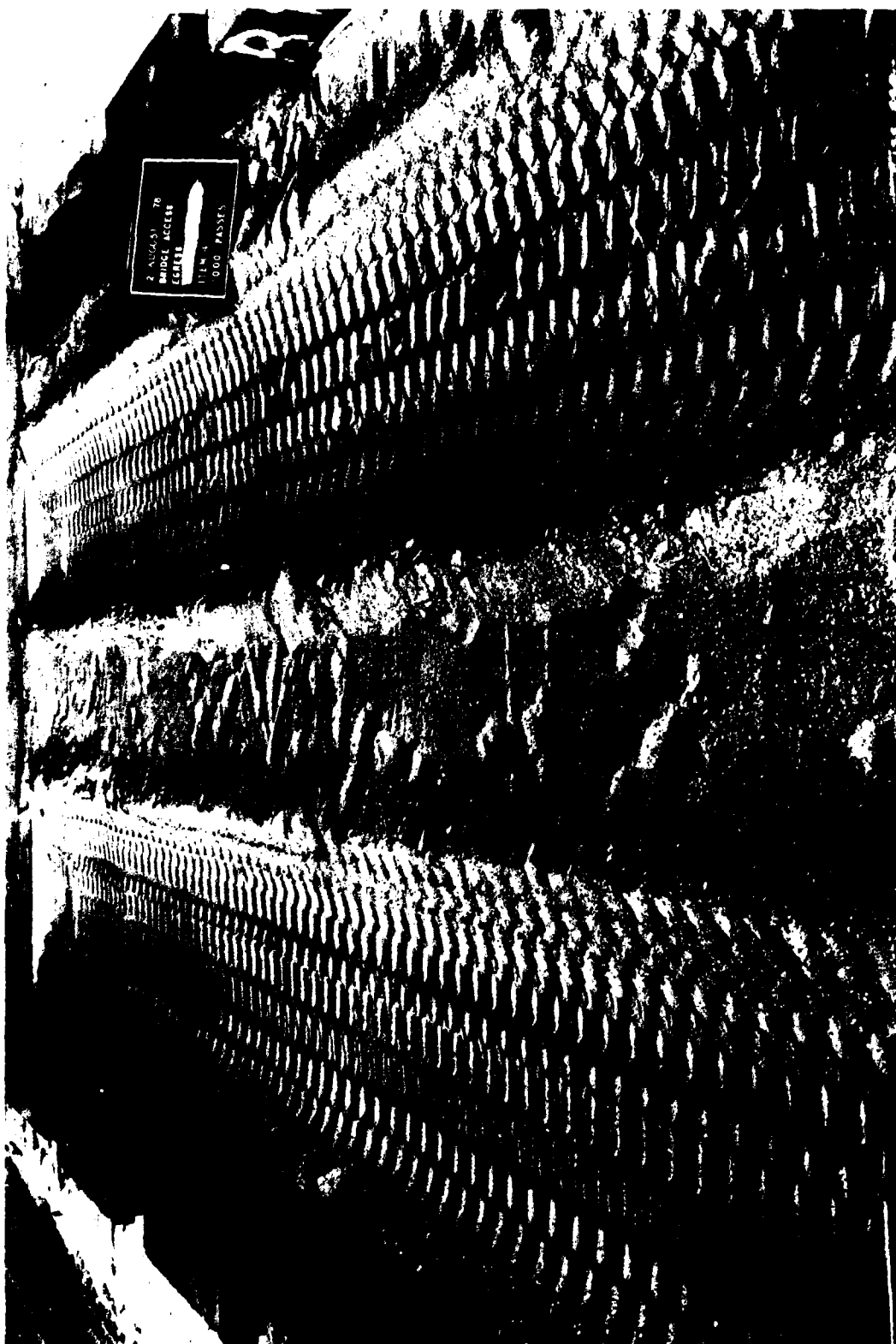
RECONSTRUCTED-WEIGHTS ADDED

PROFILE-ITEM 4- RIGHT WHEEL PATH
IKG FIBERGLASS PANELS



PROFILE - ITEM 4 - LEFT WHEEL PATH
IKG FIBERGLASS PANELS

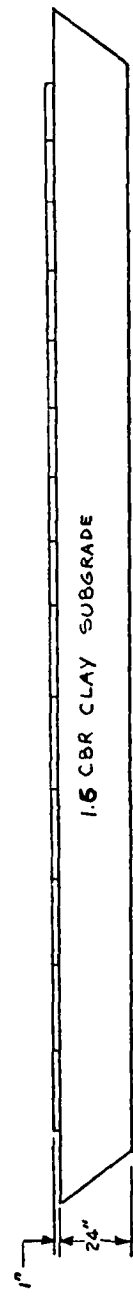
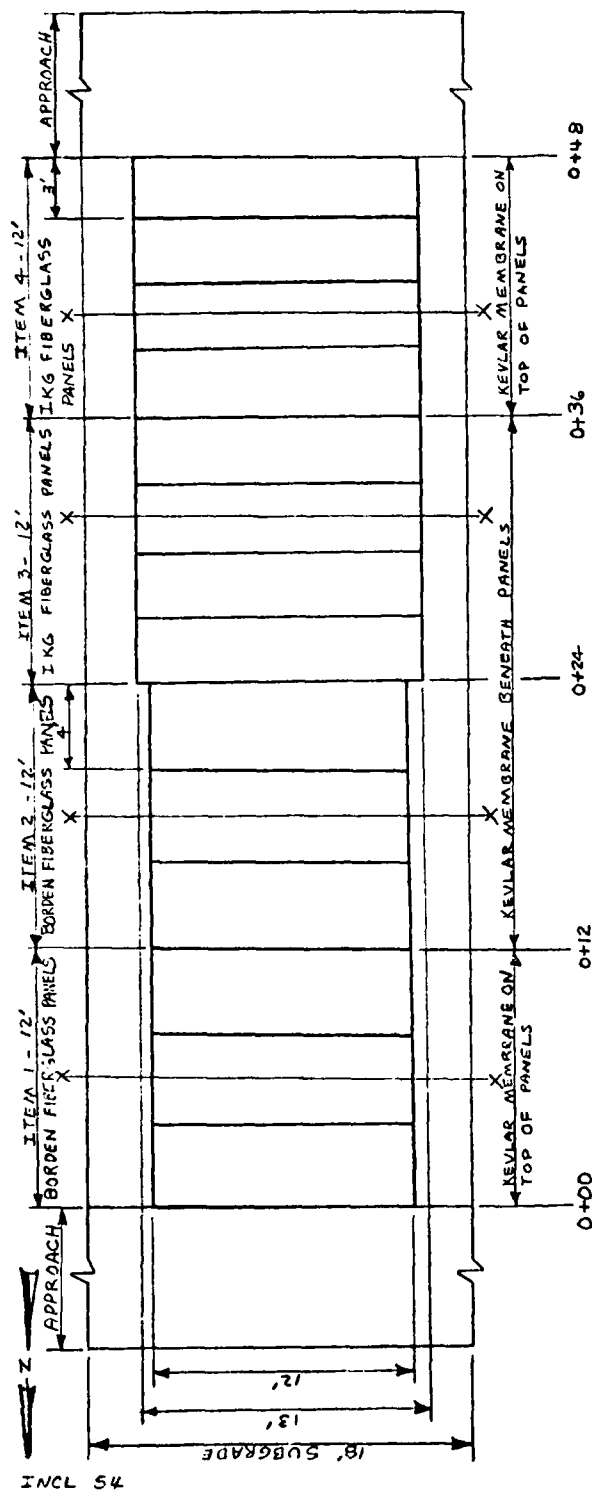
INCL 52 PP. 1



Item 4 after 1000 passes

Incl 53.

372



X—X CROSS SECTION DATA POINTS

TEST SECTION LAYOUT BORDEN AND IKG FIBERGLASS PANELS WITH/WITHOUT MEMBRANE



Test section (heavy clay subgrade) prior to traffic

SUMMARY OF CBR, WATER CONTENT, AND DRY DENSITY

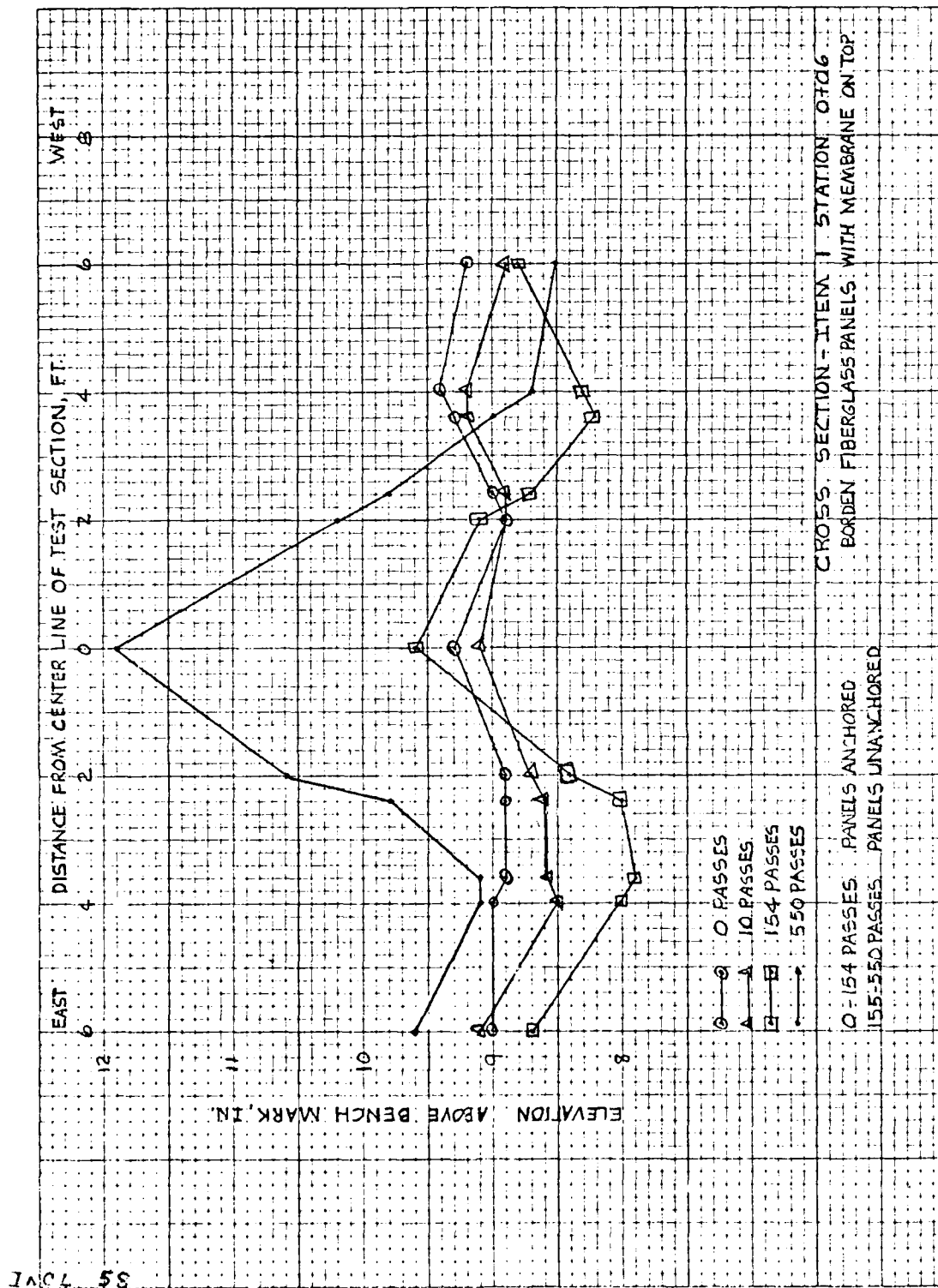
<u>Total No. of Passes</u>	<u>Location of Test Pit</u>	<u>Depth, in.</u>	<u>CBR</u>	<u>Rated CBR</u>	<u>Water Content, %</u>	<u>Dry Density, pcf</u>
0	Sta 0+24	Surface	1.4	↑ 1.6 ↓	31.6	86.2
		6	1.5		34.2	84.8
		12	<u>1.8</u>		<u>33.3</u>	<u>85.2</u>
		Avg.	1.6		33.0	85.4
550	Sta 0+10	Surface	1.7	↑ 1.6 ↓	34.2	84.6
		6	1.5		32.8	84.2
		12	<u>1.7</u>		<u>34.4</u>	<u>82.1</u>
		Avg.	1.6		33.8	83.6



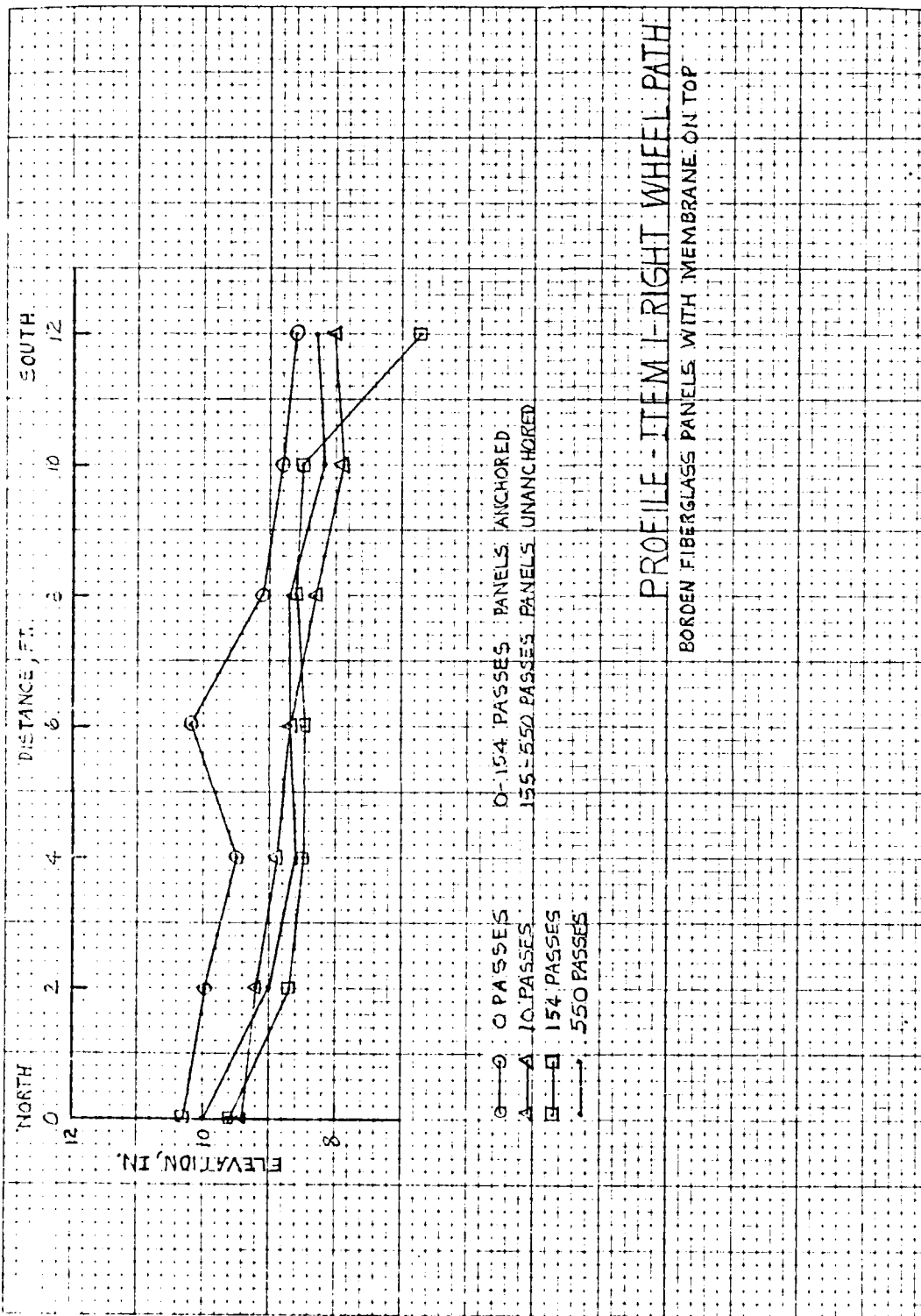
Item 1 prior to traffic

Incl. 57.

376



INCL 54





Item 1 after 154 passes of traffic

Incl 60.

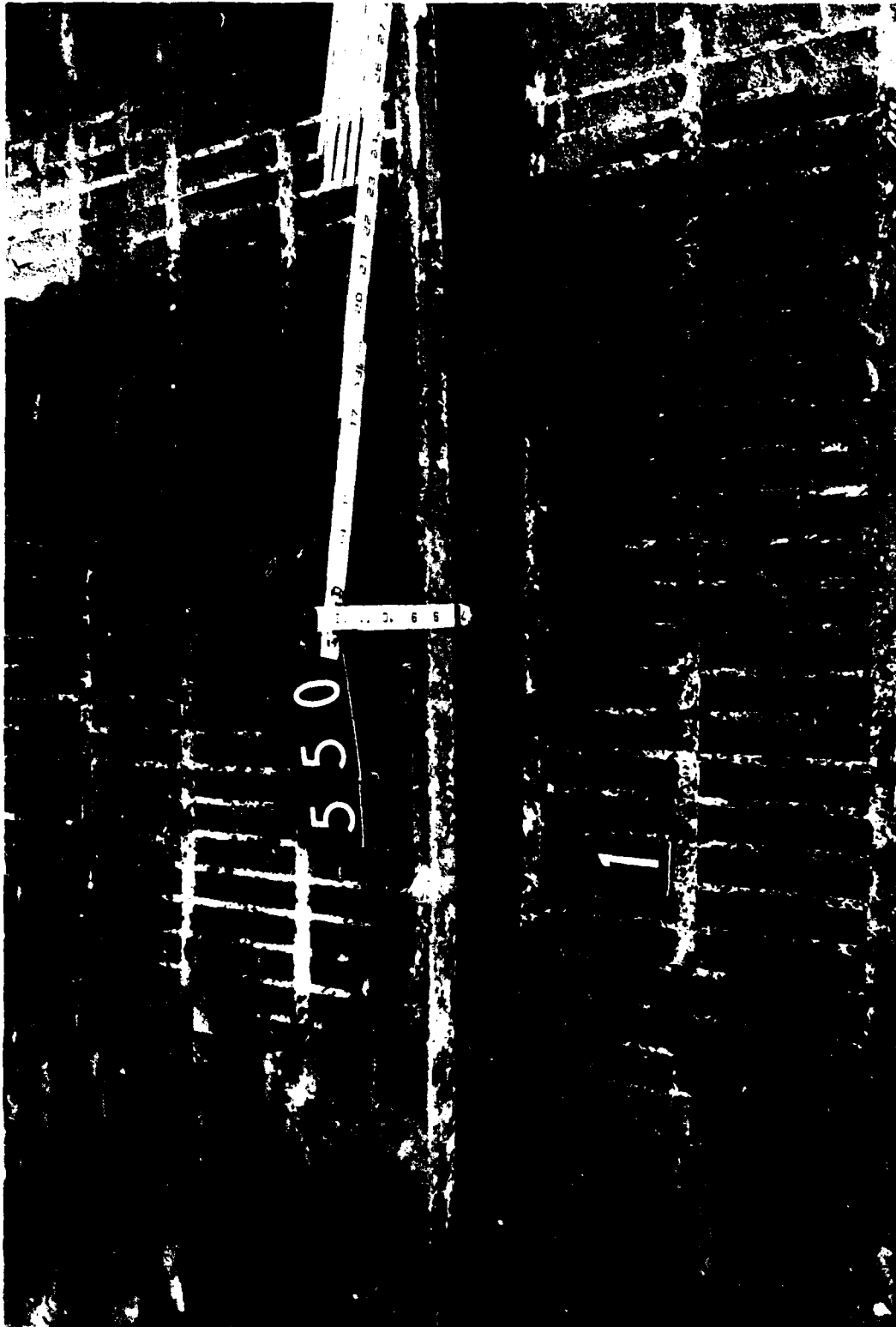
379



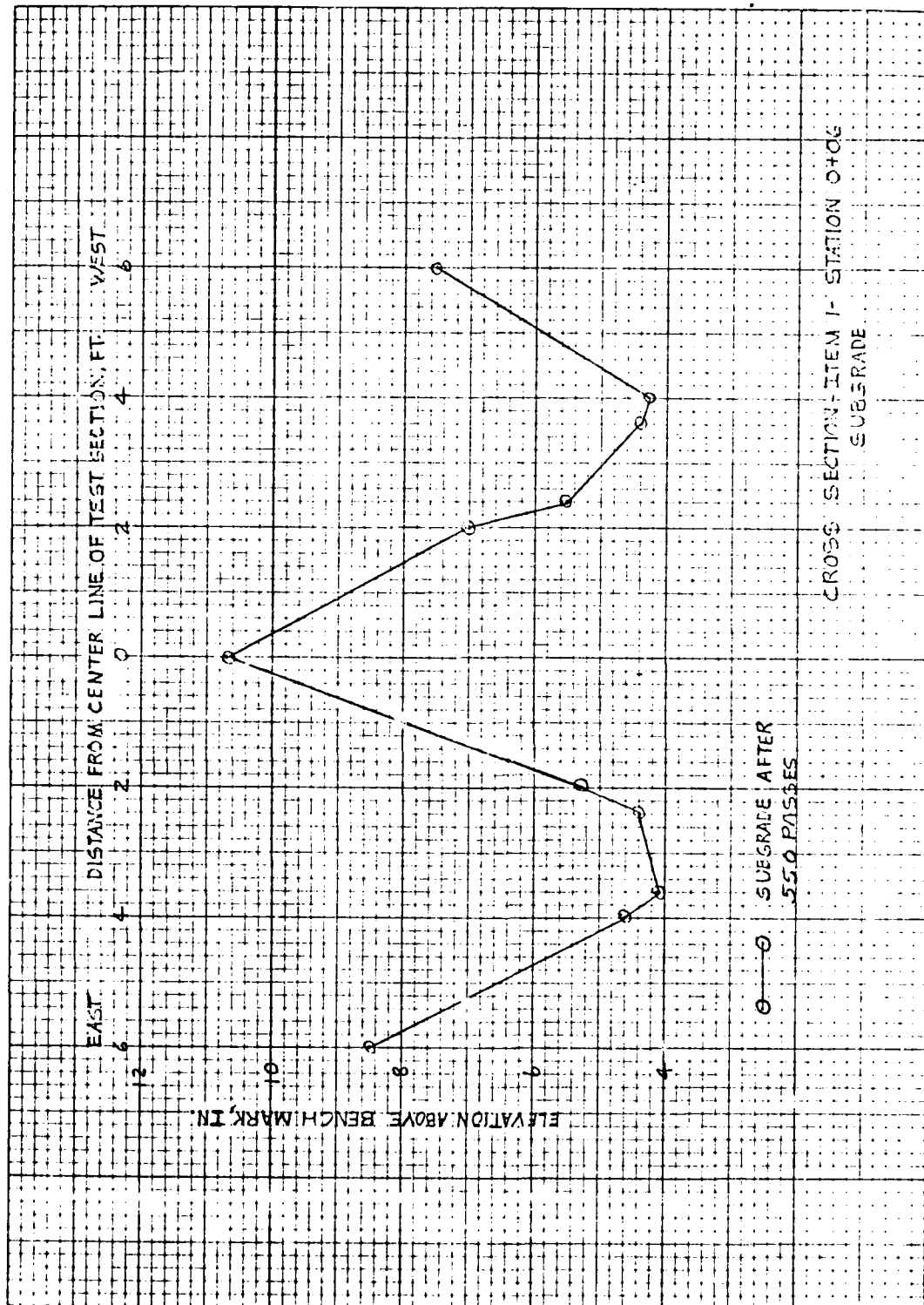
Item 1 after 550 passes of traffic

Incl 61.

380



Panels in item 1 bridging subgrade after 550 passes



INCL 63

AD-A139 480

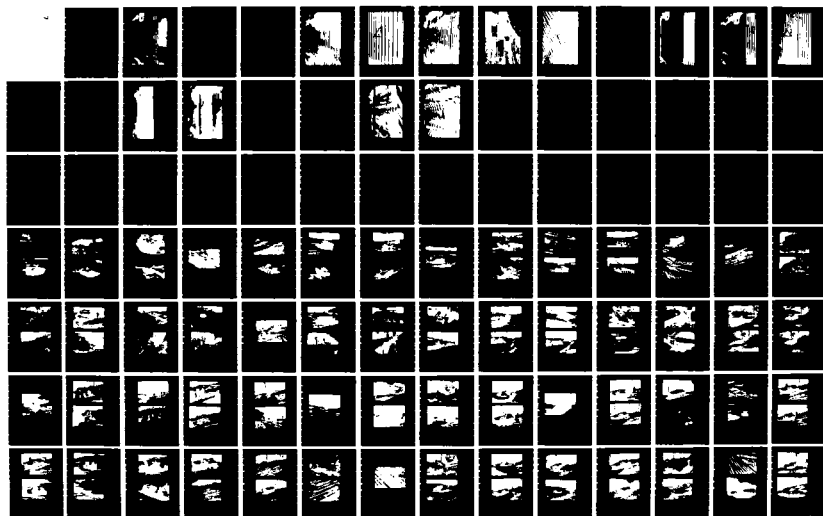
TACTICAL BRIDGE ACCESS//GRESS PRELIMINARY
INVESTIGATIONS(U) ARMY ENGINEER WATERWAYS EXPERIMENT
STATION VICKSBURG MS GEOTECHNICAL LAB B A MATIS SEP 80

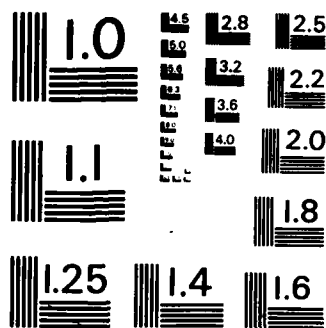
5/6

UNCLASSIFIED

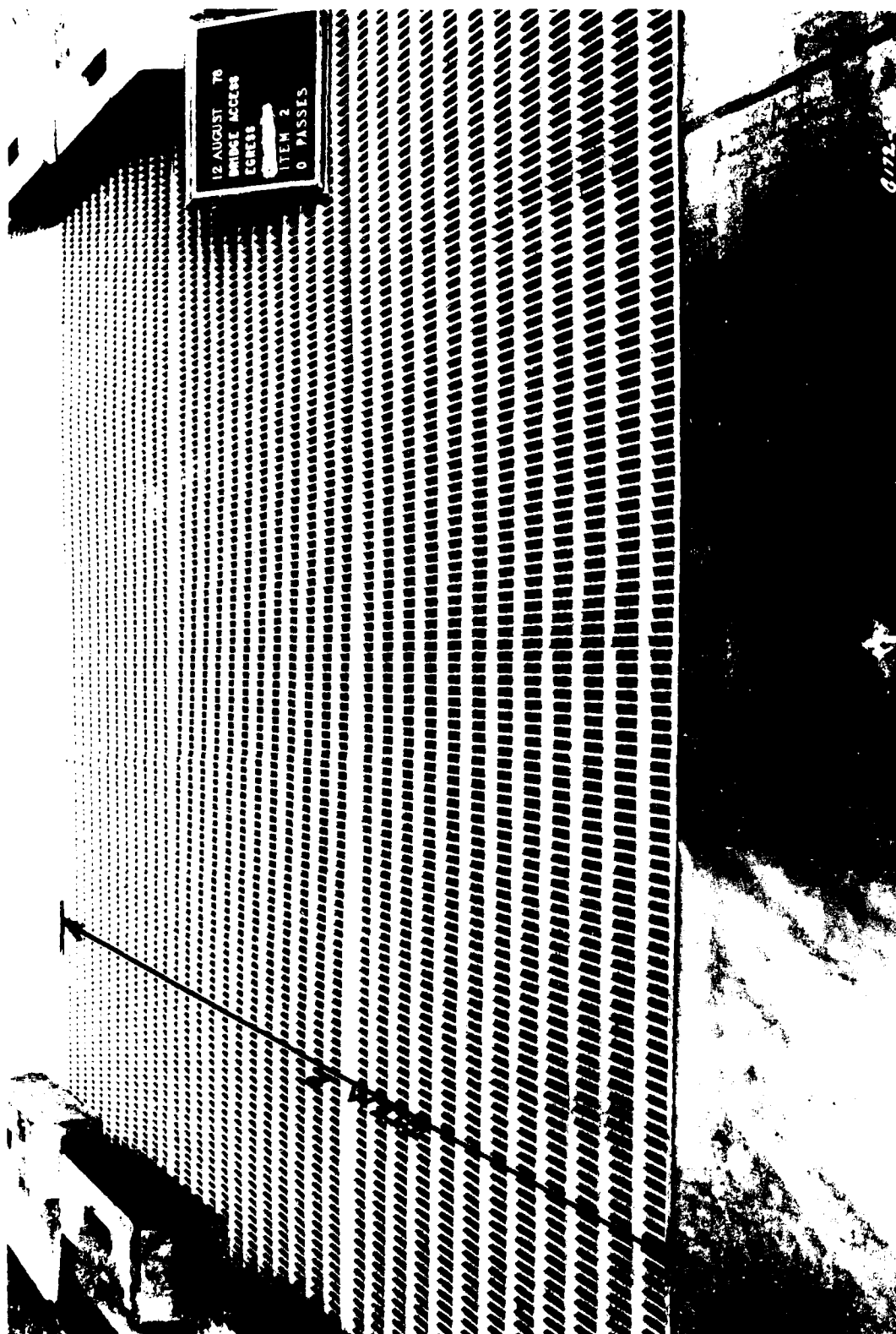
F/G 13/2

NL



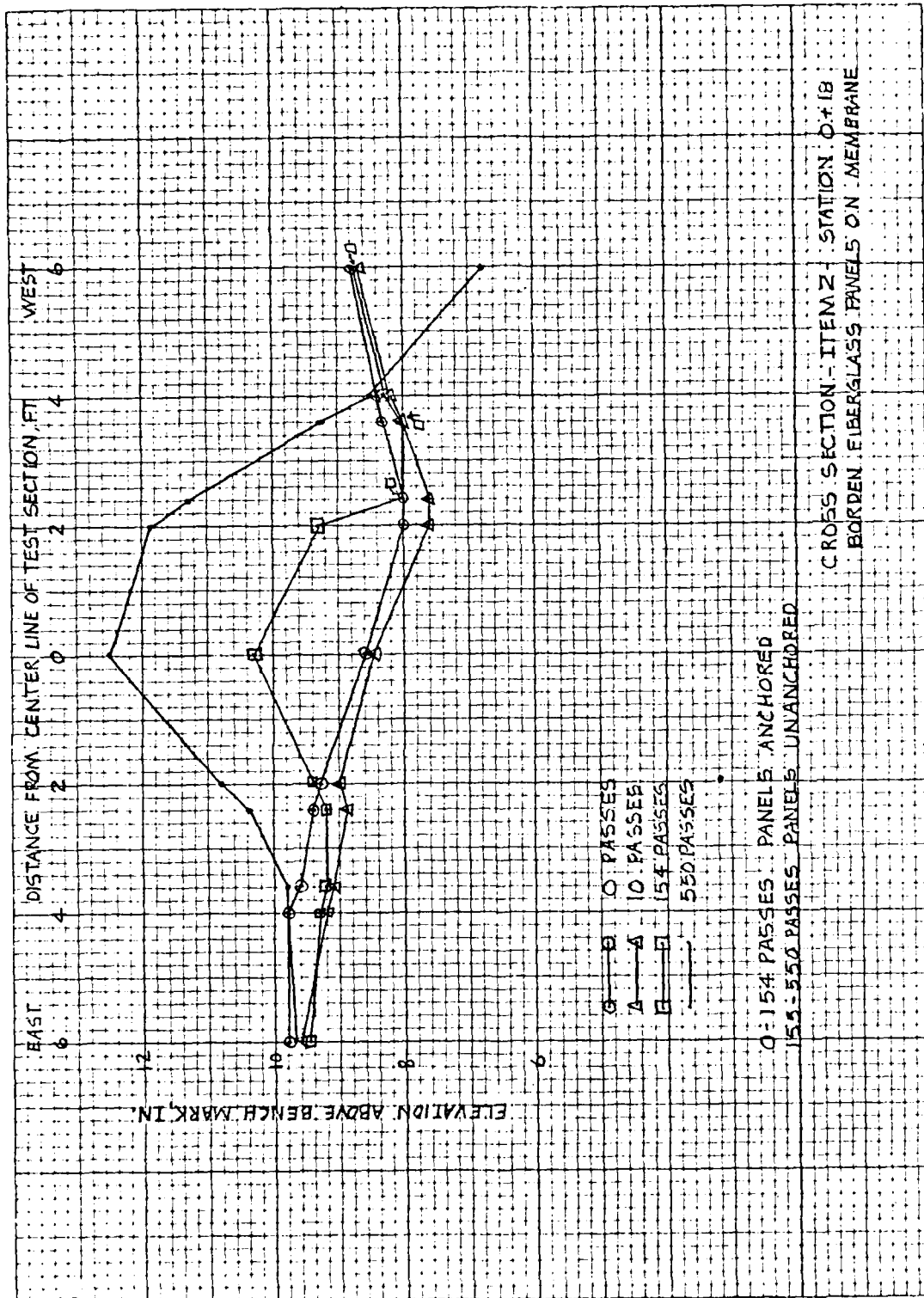


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

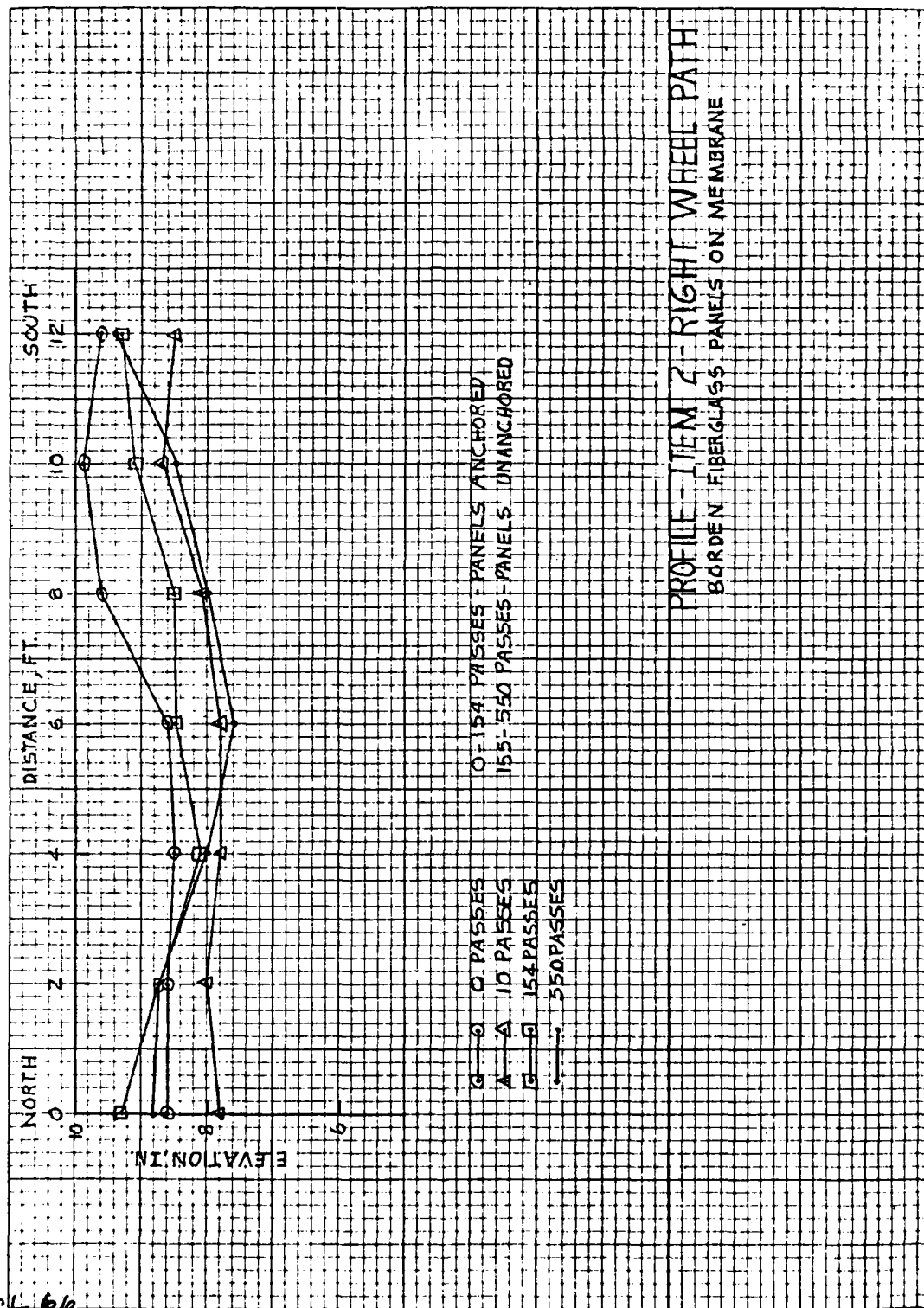


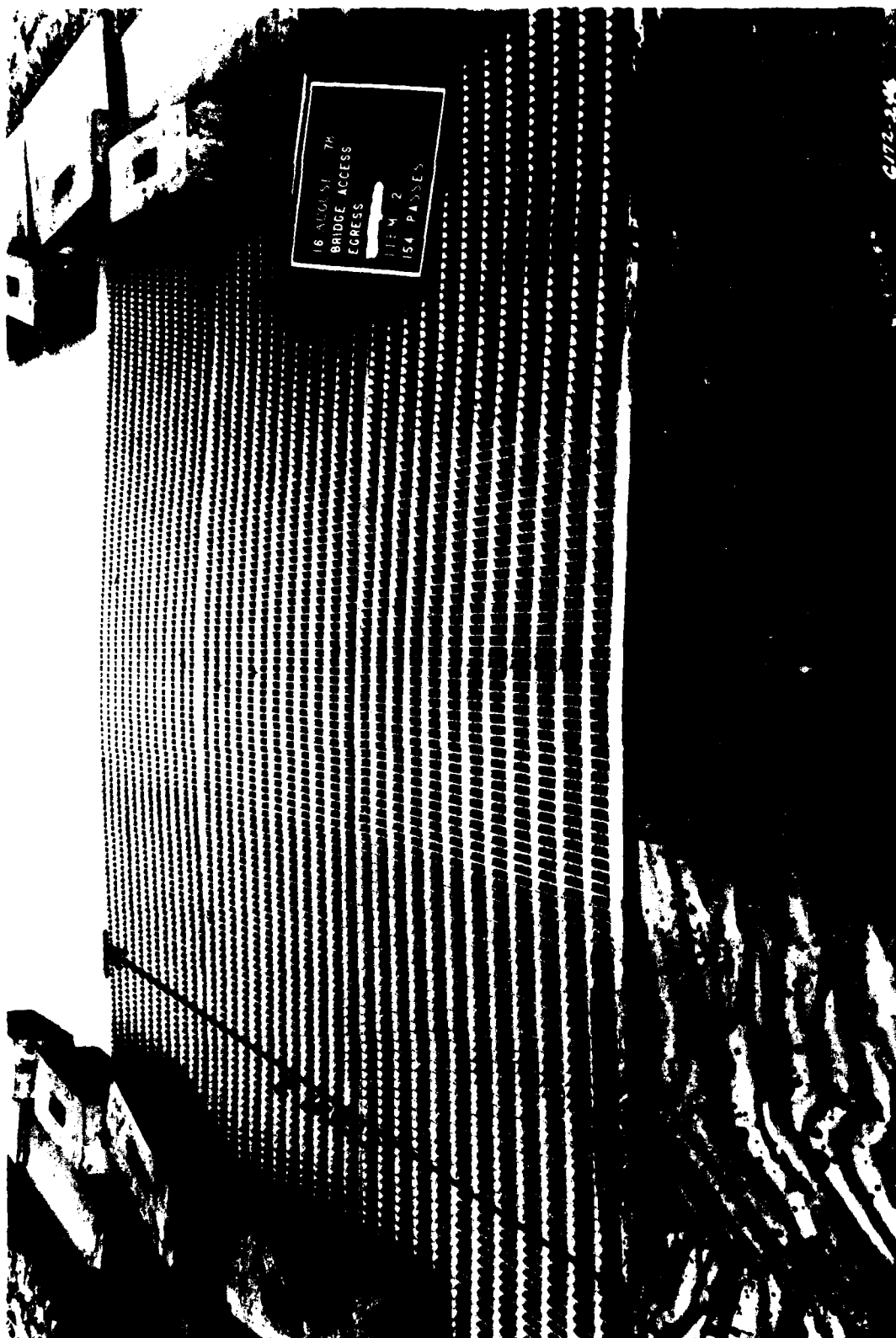
Item 2 prior to traffic

INCL 65



INCL 66



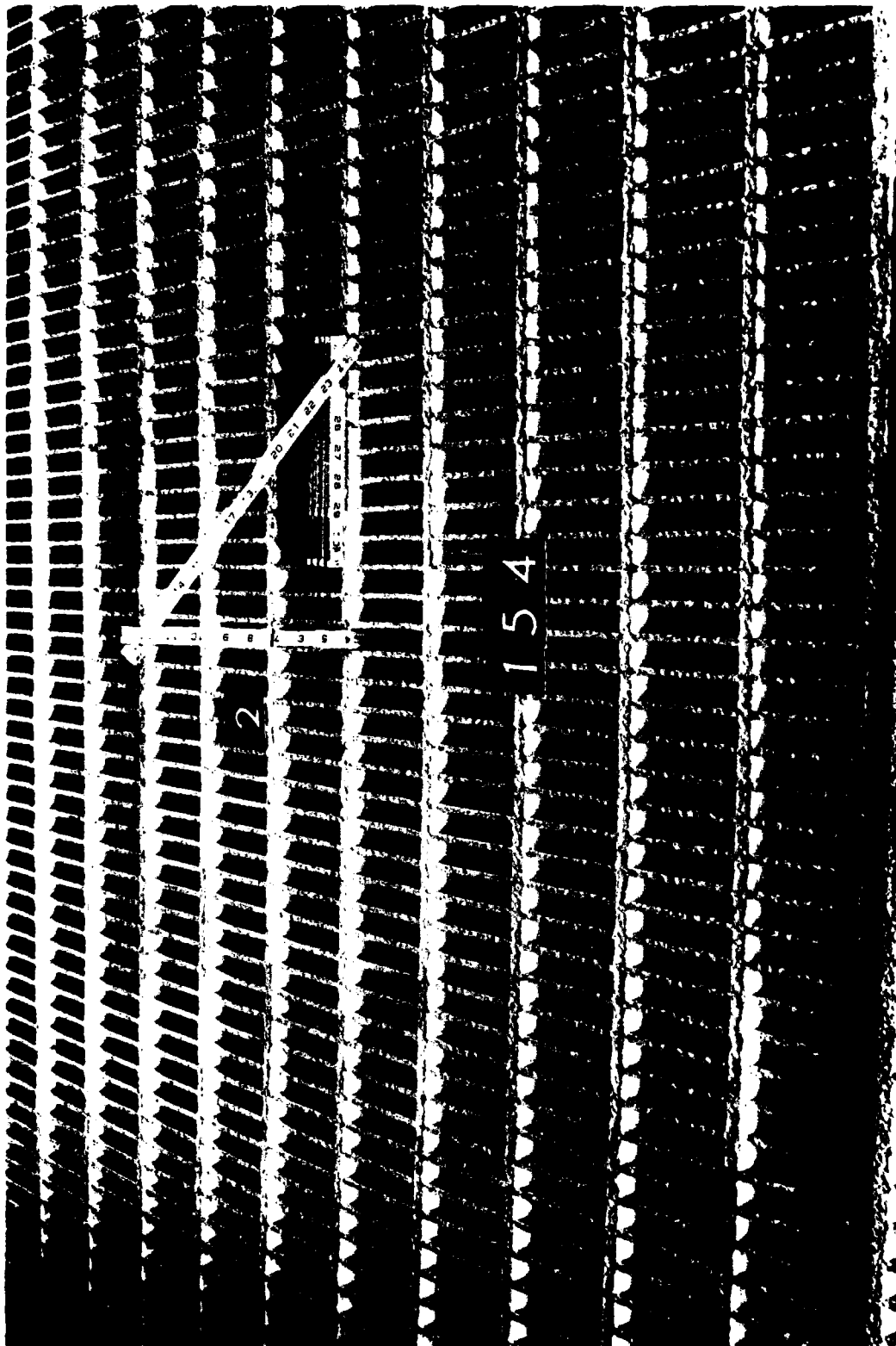


Incl 67

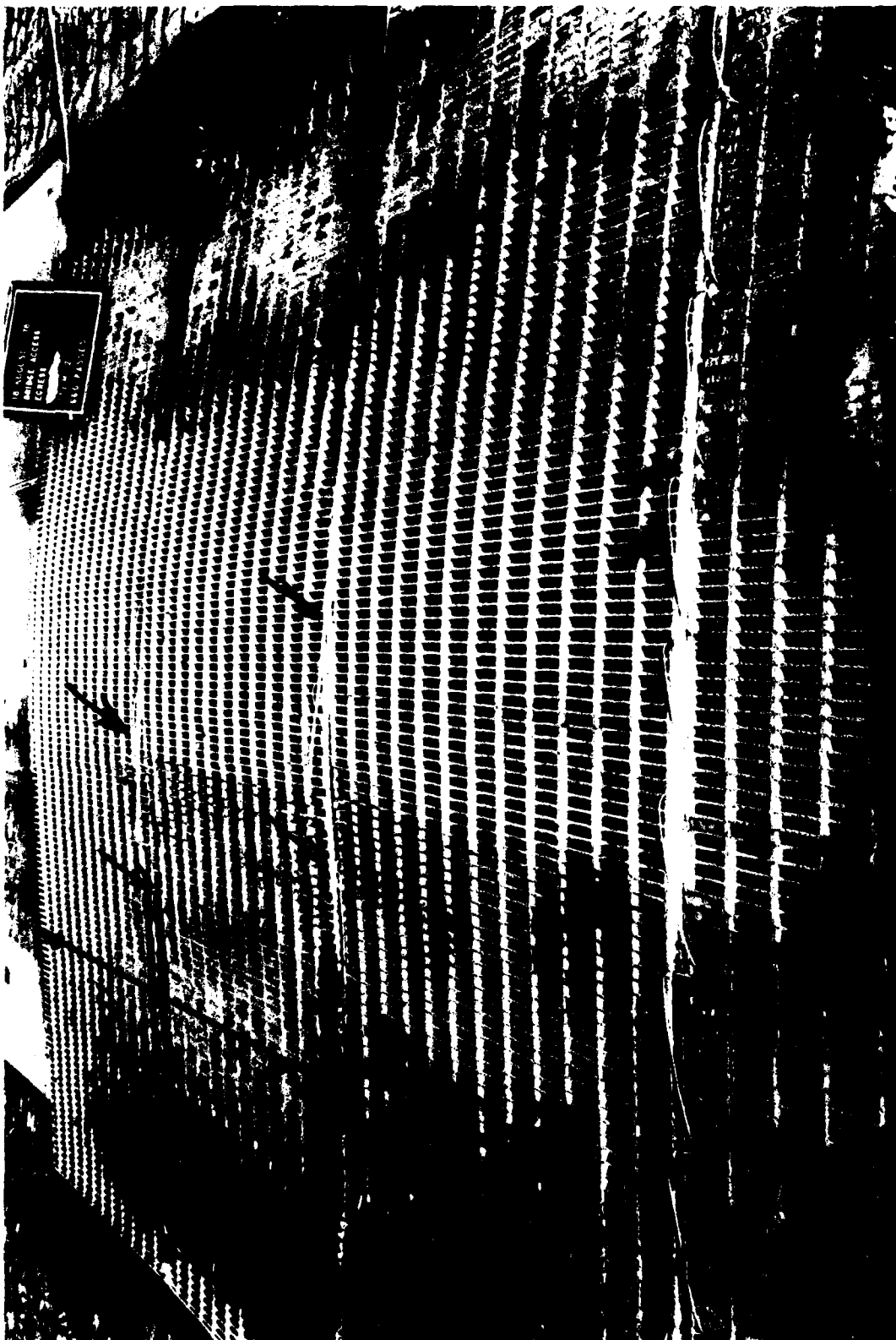
386

Item 2 after 154 passes of traffic

C172-245



Panels in item 2 bridging subgrade after 154 passes



Item 2 after 550 passes of traffic

Incl 69.



Test vehicle on test section after 550 passes of traffic

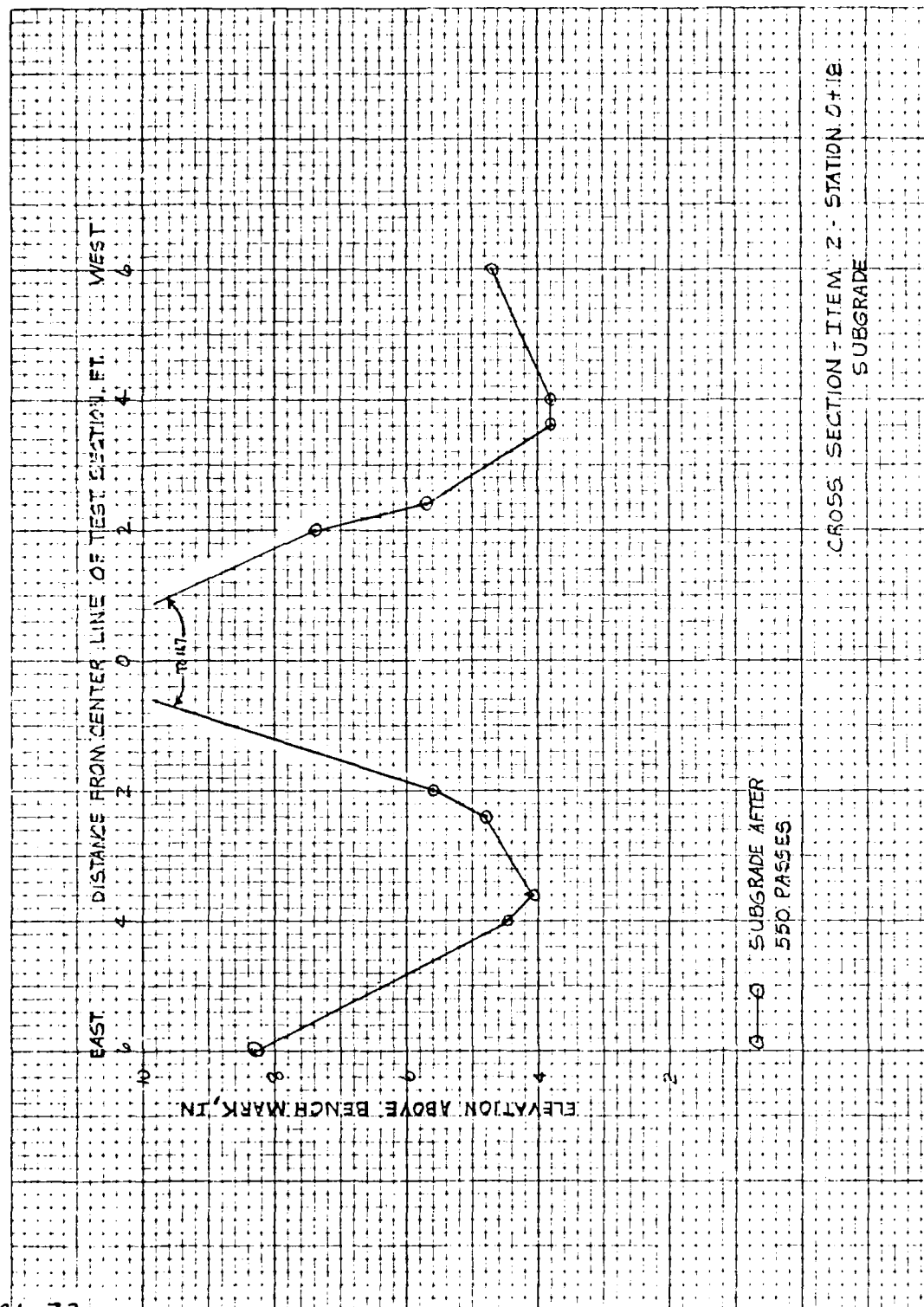
Incl 70.

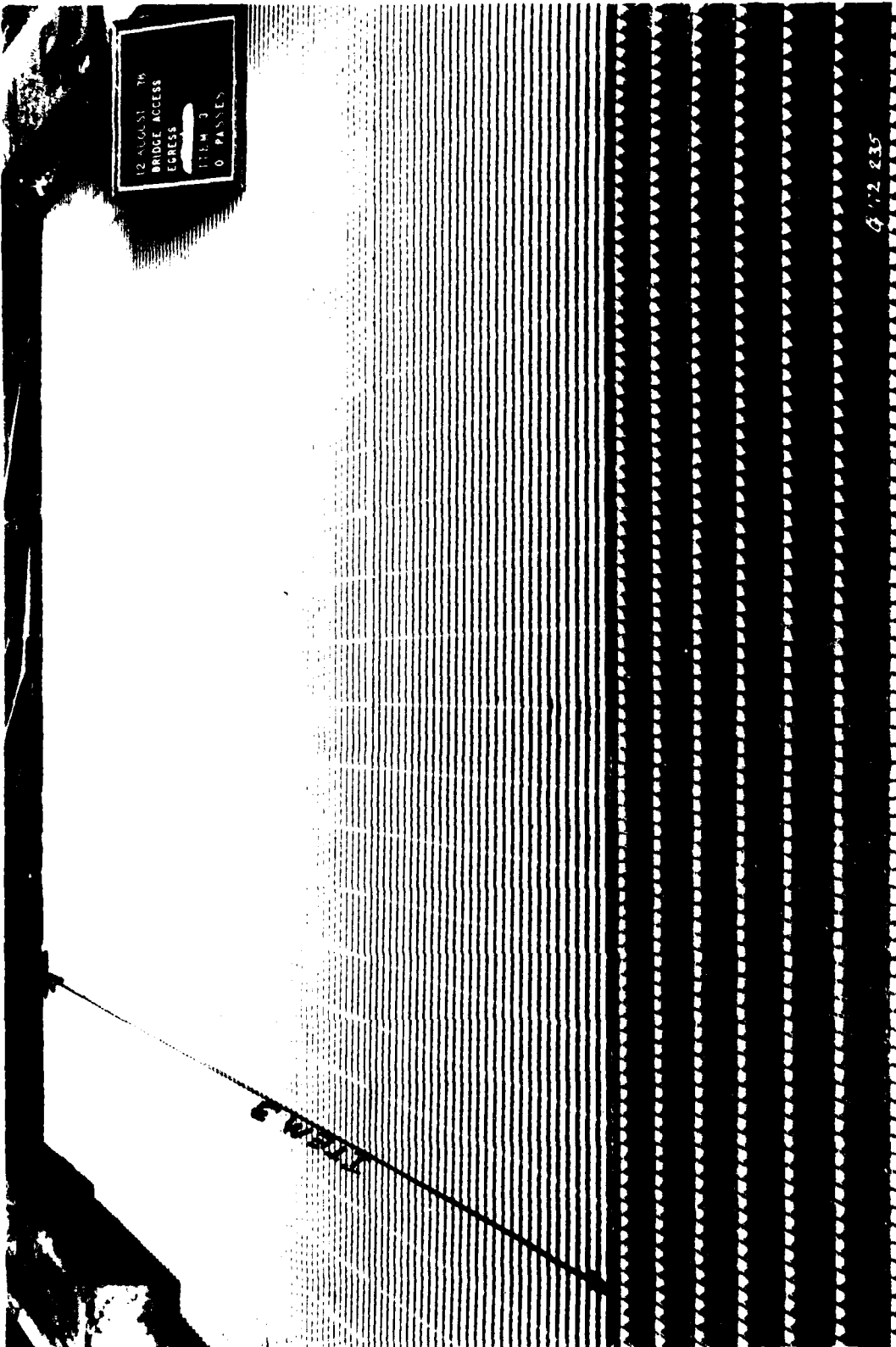
389



Panels in item 2 after 550 passes
of traffic

INCL 72





Q 12 235

Item 3 prior to traffic

Incl 73.

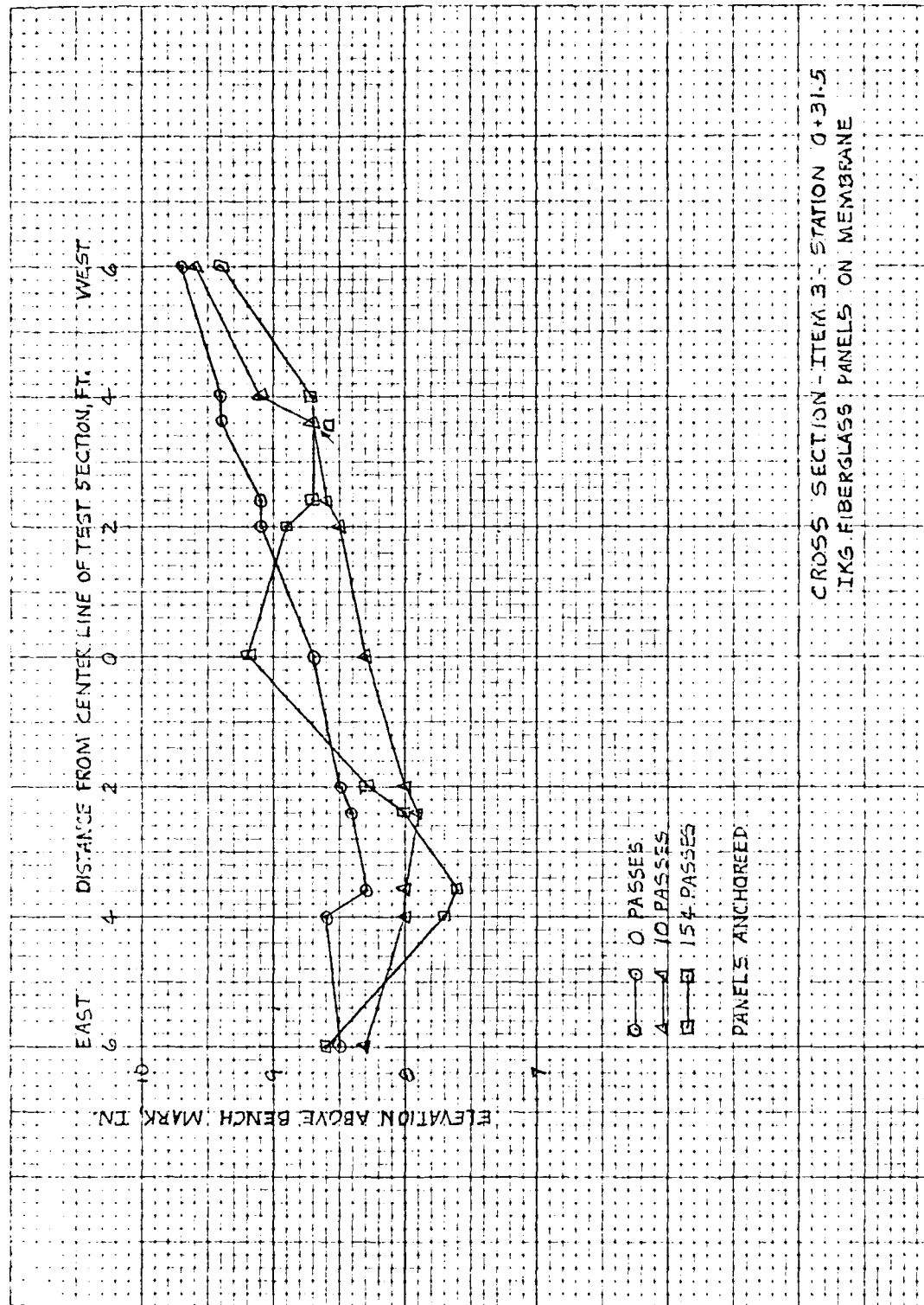


Item 3 after 154 passes of traffic

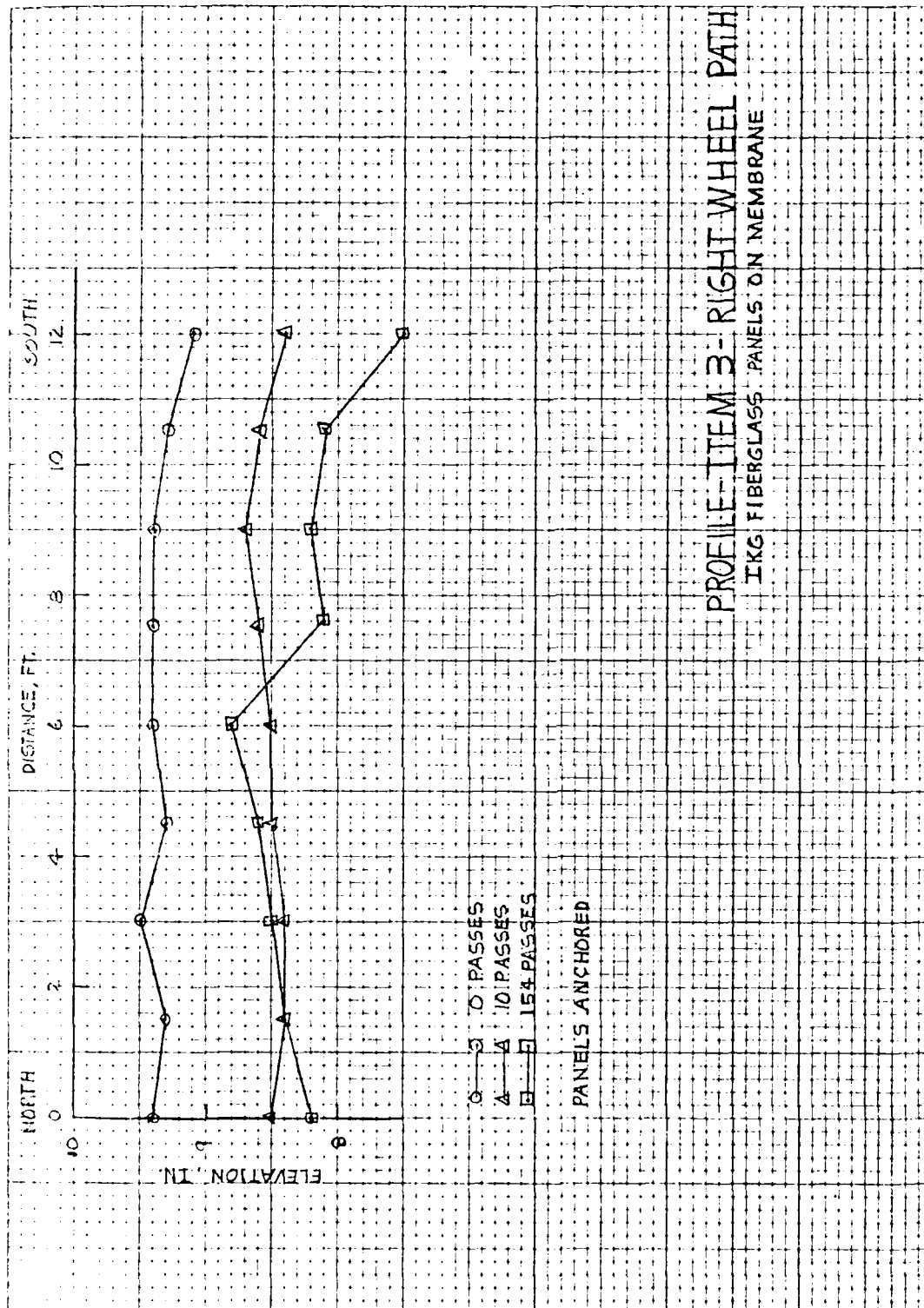


Close up of failures in item 3 after 154 passes of traffic

TABLE 7



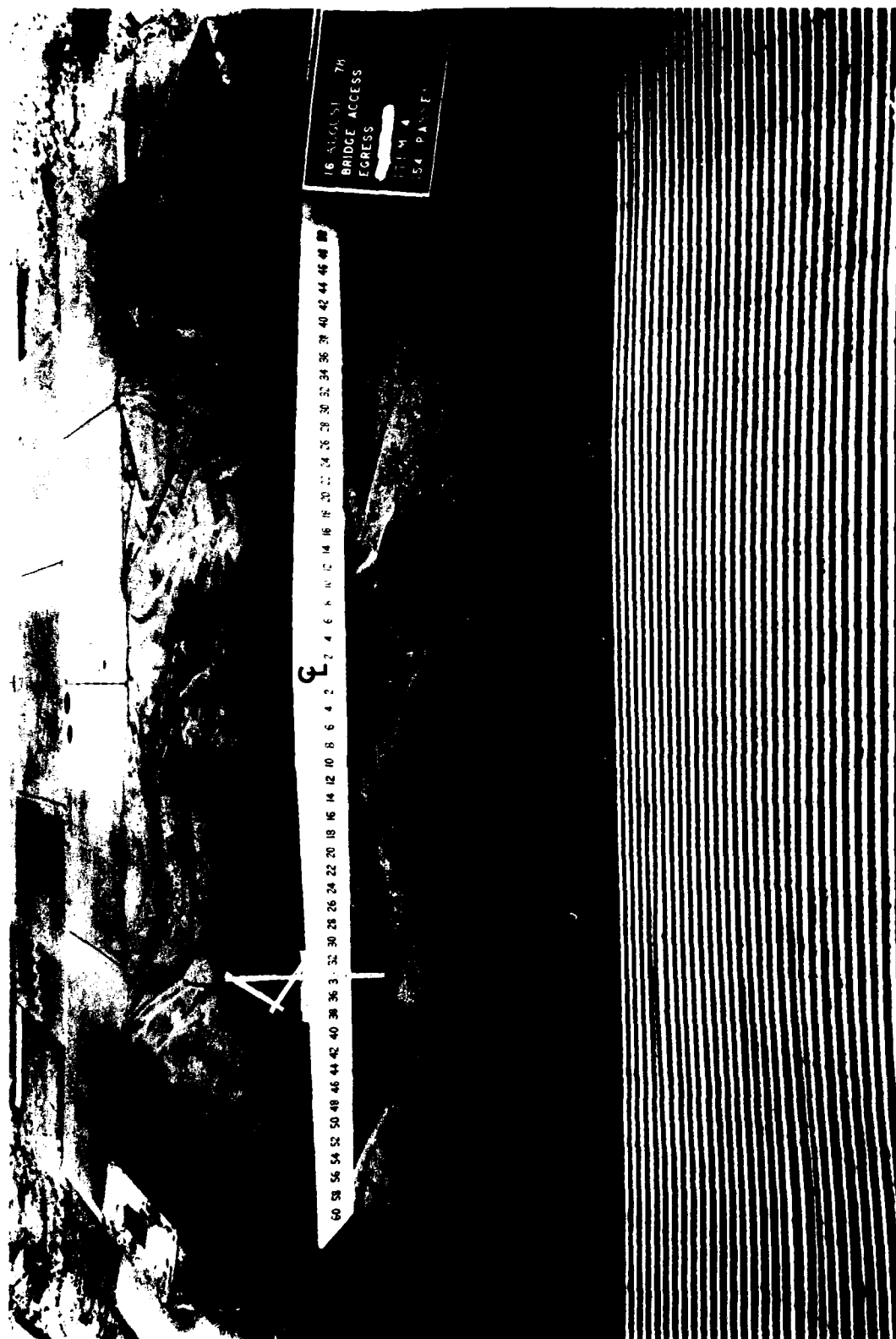
16.75 IN





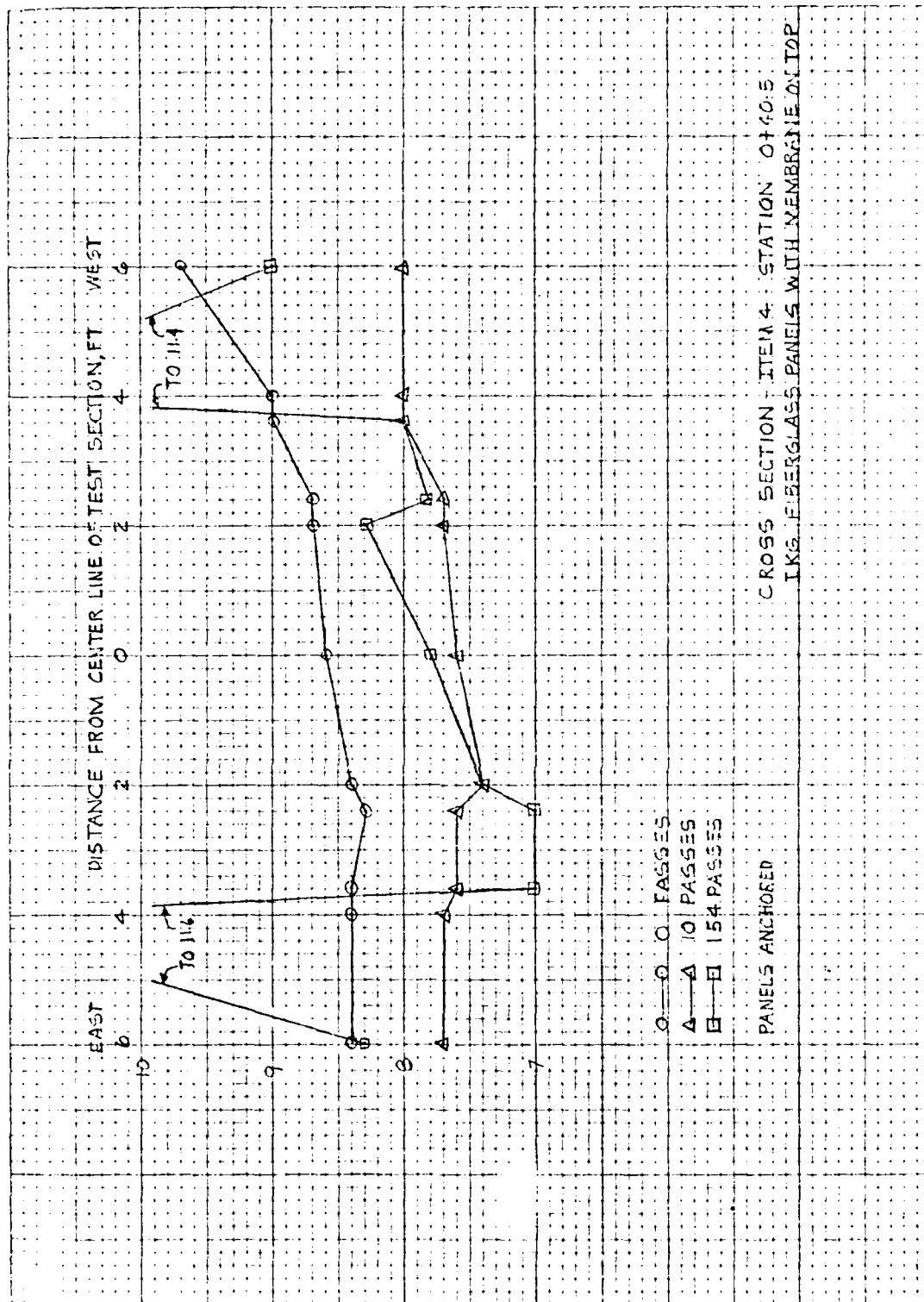
Item 4 prior to traffic

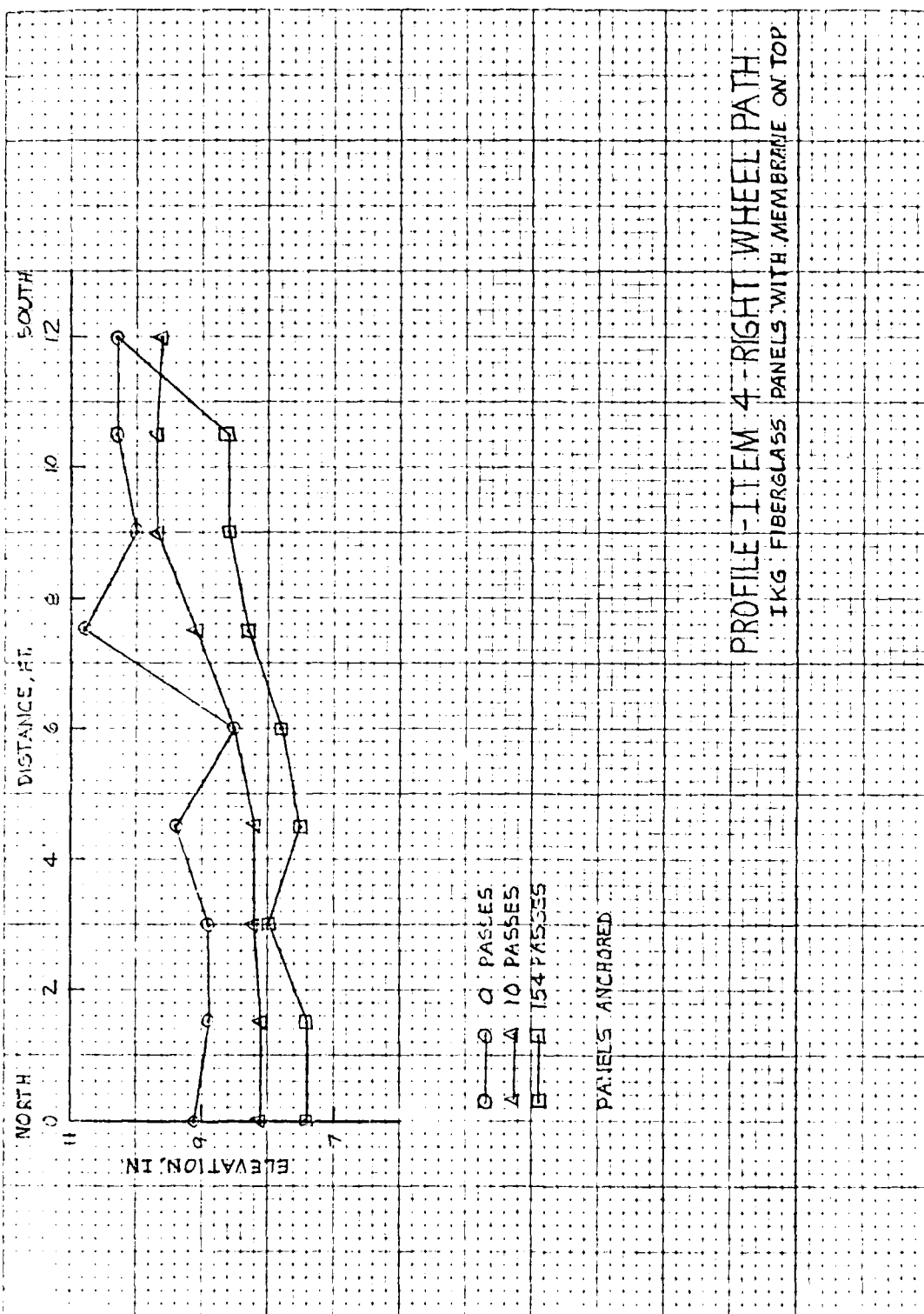
Incl 78.



Item 4 after 154 passes of traffic

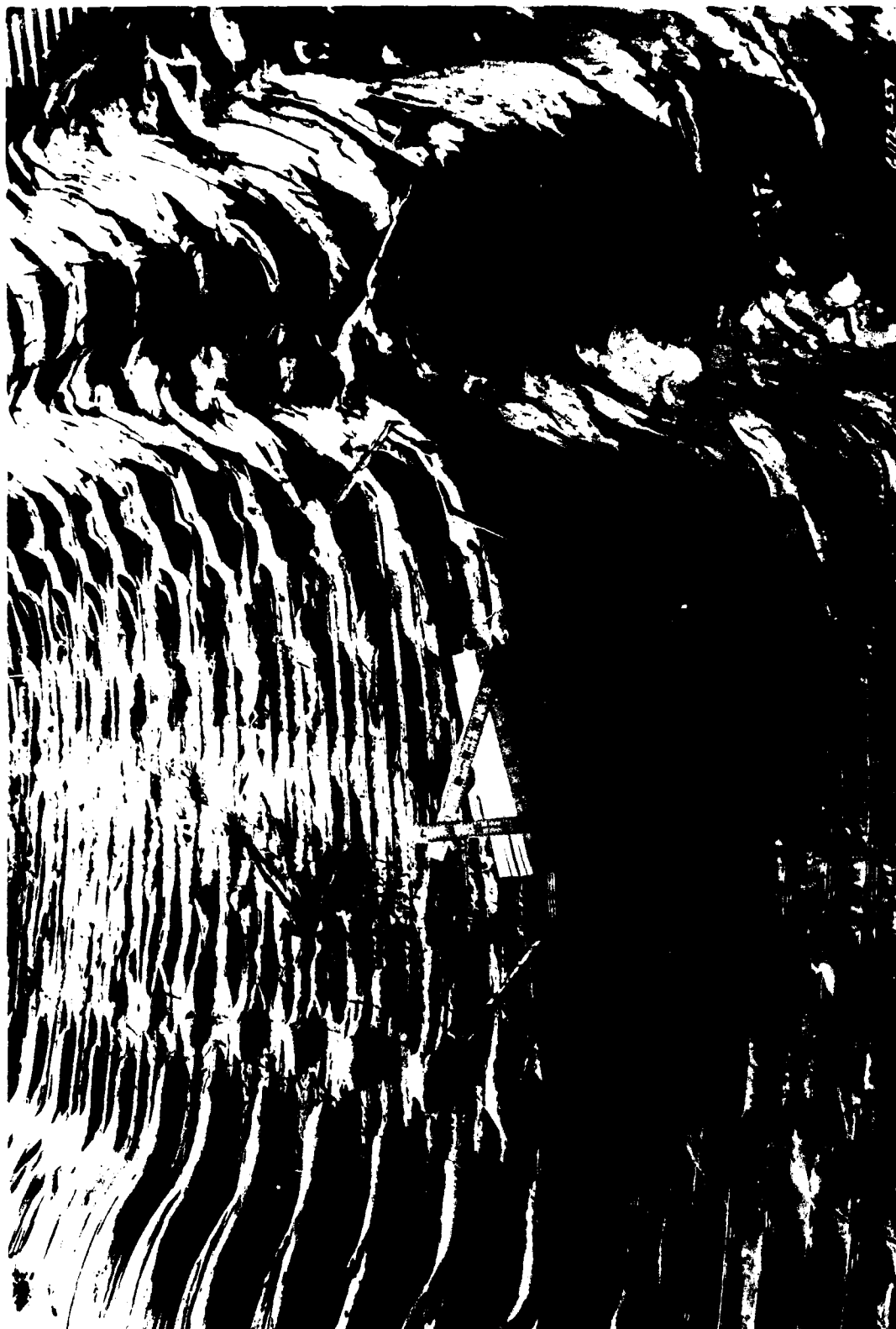
TABLE 1







from 4 after 154 passes of traffic; membrane removed from surface



Wheel path in item 4 after 154 passes of traffic; membrane removed from surface

APPENDIX H

TRAFFIC SLOPE TESTS OF MILITARY INVENTORY ITEMS
AND THEIR EFFECTIVENESS IN RIVERINE
EGRESS TESTS

Introduction

Background

1. Military operations in the 1980 time frame will require rapidly emplaced gap crossings to enable troops to effectively counter enemy threats. Emplaced gap crossings must be capable of allowing mission essential traffic to cross before enemy threats are effectively applied and maintaining subsequent traffic flow. Poor soil conditions or steep slopes along river and streambanks must be overcome to allow movement by tactical assault vehicles at the most tactically advantageous locations (Headquarters, Dept. of the Army, 1976).*

2. In concept, the desired egress capability will be used primarily in the assault phase of tactical riverine crossing operations (Headquarters, Dept. of the Army, 1979). Ideally, the capability should be obtained through the use of inventory depot items by engineers in the main battle area to aid the riverine crossing of swimming and fording vehicles and to gain access to bridges or raft loading points for assault and follow-up forces (Headquarters, Dept. of the Army, 1978).

3. Initially, some modifications or adaptations of standard inventory surfacings or soil strengthening materials will be used in an attempt to meet the goals stated in the Letter of Agreement (LOA) (Welker, 1979) by day or night. Swimming and fording combat vehicles should be able to exit streams with slopes within the normal climbing capability of the vehicles (<25 percent). In addition, egress points must be capable of withstanding 25 passes by vehicles up to and including Military Load Class (MLC) 60. The egress "system" envisioned in the LOA will hopefully enable one squad of an engineer combat company, using current equipment, to simultaneously install two 5-m-wide egress systems (adjacent on the bank) within 15 min after arrival at the exit bank.

Purpose and scope

4. During the period July-September 1978, personnel of the

* References cited in this appendix refer to REFERENCES at the end of the main text.

Geotechnical Laboratory, U. S. Army Engineer Waterways Experiment Station (WES), conducted egress tests within the boundaries of the WES reservation. Two areas were selected, one upland area adjacent to Porters Chapel Road and the other area adjacent to the north end of Brown Lake. Slopes of 23-25 percent were selected in silty clay (CL) soil adjacent to Porters Chapel Road and lean clay (CL) soil near Brown Lake. Each area was graded smooth. Slope-climbing tests were conducted with a combat-loaded M54 dump truck and two tracked vehicles, the M48 tank and M113 armored personnel carrier (APC). Tests were conducted on bare slopes, on T17 membrane surfaced slopes, and on M19 and M8A1 mat-surfaced slopes, both dry and wet. Also tests were conducted where the vehicles tracked through a wet clay at the toe of the slope. In addition, drawbar pull tests were conducted with the M113 APC on T17 membrane stretched and anchored on level ground. The purpose of these tests was to determine if any depot inventory items were suitable, and to what degree, to use as access/egress surfacing for a riverine crossing in a combat assault role.

Test Program

Upland area tests

5. Unsurfaced slopes. Initial tests were conducted on the WES reservation on 25 percent slopes constructed in a roadbank of medium-brown silty clay (CL). Tests were conducted with the M113 APC at a gross vehicle weight of 22,865 lb; the M54, 6x6, dump truck at 70 psi and 40,000 lb, and the M48 tank at 106,000 lb. Results of these tests are shown in Table 4 (see main text).

6. The initial sequence of tests was conducted on a dry, unsurfaced soil with no membrane or mat surfacing. All three vehicles completed the required 25 passes on the dry slope, and the rut depth after traffic by all vehicles was 4-1/2 in. However, when wetted with spray from a water truck, the surface became very slippery, and vehicle performance was reduced considerably. The M113 APC completed two passes, the M54 truck no passes, and the M48 tank one pass (Table 4). Photo H1 shows the area and vehicles on the slope when dry and also when wet.

7. M19 mat-surfaced slopes. The next sequence of tests was conducted on another 25 percent silty clay slope near the one used for the previous tests. The slope was covered with clay gravel and then with a 4- by 4-ft M19 mat (Green and Ellison, 1969; Depts. of the Army and Air Force, 1968; Headquarters, Dept. of the Army, 1965, 1966a, 1968, and 1973) anchored (Gerard, 1969) to the slope. Initially, the vehicles attempted slope-climbing tests on the mat in the dry condition. All vehicles completed the required 25 passes (Photo H2 and Table 4) although the mat slid downhill slightly in the M113 test series and nearly 7 in. in the M54 and M48 test series. The mat surface was then wetted with spray from the water truck (continuously during the tests), and the test series was repeated. Again, all vehicles completed the required 25 passes. The mat movement was similar to that in previous tests except that in the M54 tests only 1-1/2 in. of movement occurred.

8. In order to simulate some of the characteristics of water exit conditions, a thin layer (<4 in.) of wet clay (CH) was placed at the bottom of the mat-surfaced slope and water was again sprayed on the M19 mat. The performance of the M113 APC was affected slightly by the wet clay at the bottom of the slope, and the vehicle completed with difficulty the required 25 passes. However, the M54 truck was unable to complete a single pass, and the M48 tank could complete only five passes with extreme difficulty, because of the surface slipperiness caused by the wet clay and water.

9. Similar tests with the same M19 mat, unanchored, and with the same surface conditions produced similar results (as the anchored) but with substantial mat movement as shown in Table 4. Wet clay tests were not conducted, as previously described, but similar results could most probably be expected.

10. M8A1 mat-surfaced slopes. Tests similar to those above were performed at the same site using the M8A1 (Headquarters, Dept. of the Army, 1973; Tucker, 1968; and Garrett, 1959). Mat placement (top side up) began at the toe of the slope in the normal brick placing pattern as shown in Figure H1, except the ends were offset approximately 1 ft. The mats were anchored in the offset area. Tests were conducted with the

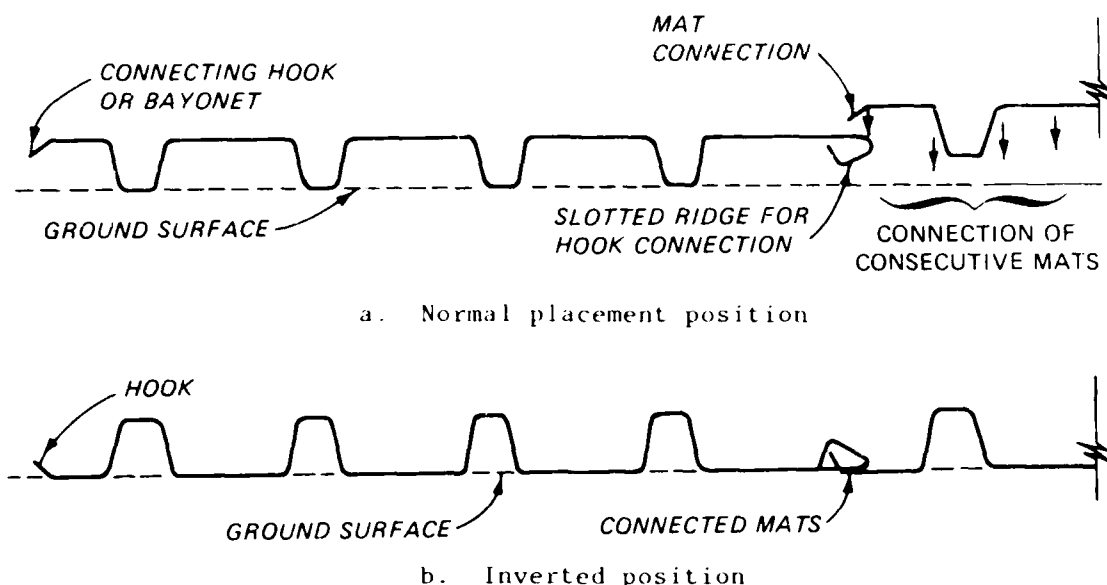


Figure H1. Normal and inverted placement positions of M8A1 mat

M113 APC, M54 truck, and M48 tank on the mat initially in the dry condition. All three vehicles were able to complete 25 passes with little mat movement downslope (Table 4). The mat surface was then sprayed with water from the water truck, and all three vehicles operated up the slope. Again, all three vehicles were able to complete the required 25 passes with little difficulty, although slightly more downhill mat movement occurred in these tests than in the dry surface tests. No tests were conducted with the wet clay layer at the base of the slope with the anchored mat.

11. The anchors were removed from the M8A1 mat on the same slope, and tests were begun with the unanchored M8A1 in the dry surface condition. All three vehicles were able to complete the required 25 passes with about the same mat movement as in the anchored tests (Table 4). The surface was sprayed with water, and tests were conducted with the three vehicles. All three vehicles were able to complete 25 passes with approximately the same mat movement as in the anchored tests. A thin layer of fat clay (CH) was placed at the bottom of the mat-covered slope, and tests were conducted with the three vehicles while the mat and clay

surfaces were sprayed with water. Results of these tests were similar to those of the M19 tests. The M113 APC was able to complete 25 passes with difficulty, and the M54 truck attempted three passes and completed none, while the M48 tank completed three passes with difficulty (Photo H3). Mat movement in all three test series was negligible.

12. Because of the design features of the M8A1 mat (Figure H1), the mat appears to provide better tractive surface (for vehicles) in the inverted position than in the normal placement position. Accordingly, the mat used in the previous tests was overturned and reanchored, and tests were conducted on the same 25 percent slope (with clay). The M54 truck was still unable to complete a single pass with the wet clay layer at the bottom of the slope, whereas the tracked M113 and M48 completed the required 25 passes with some difficulty.

13. T17 membrane-covered slopes. The area was cleared of mats, checked for 25 percent slope, and prepared for the membrane test. The graveled slope was covered with a T17 membrane (Headquarters, Dept. of the Army, 1966b) section composed of sheets of membrane bonded together. The membrane was anchored at the top of the slope by excavating a small ditch, laying the membrane inside, driving tack anchors, and covering it with the excavated material. Three tack anchors were then placed along each side of the membrane at approximately equal intervals to anchor the membrane to the slope.

14. Tests were again conducted with the M113 APC, M54 truck, and M48 tank in both dry and wet surface conditions. All three vehicles were able to complete the required 25 passes with little difficulty, although the repetitive traffic caused tears in the membrane in the wet-surfaced tests, as indicated in Table 4. Membrane movement was about the same for each vehicle in both (dry and wet) of the test series. In all tests, the membrane wrinkled and stretched with each pass but returned to almost the same point after traffic (Photo H4). Tests were also conducted with the three vehicles with the wet clay layer added at the toe of the slope. All three vehicles experienced extreme difficulty in even getting up onto the membrane-covered slope. Only the M113 APC was able to get up onto the slope, then only by using a 20-ft start on

dry soil. In all attempts, the membrane deformed considerably and was torn across the slope width and severely damaged in tests with both of the tracked vehicles.

15. During all of the tests mentioned previously, membrane abrasion by underlying gravel was considerable and even severe in some places. These abrasions, however, were not considered to be the causative factor in the membrane tearing during the tests.

Brown Lake tests

16. Tests were conducted on 23-25 percent slope constructed in lean clay (CL) at the north end of Brown Lake (Figure H2) on the WES reservation. Slope-climbing tests were conducted with only the M113 APC loaded to 23,495 lb. In addition to the vehicle tests, the time of membrane or mat placement and the number of personnel required for placement were also annotated.

17. T17 membrane-covered slopes. An 18- by 77-ft membrane section composed of bonded sheets of T17 membrane was folded into a 4- by 5- by 1-ft bundle and placed at the toe of the slope, adjacent to the water. Five men then unfolded the section and pulled 57 ft up the slope in 32 sec. Two men in two boats placed 20 ft of membrane out in the lake in 7 min and secured the membrane to the lake bottom (2-5 ft below the water surface) with sandbags attached to the membrane pad with ropes. Three men then placed four 1-ft-long side anchors in 1-1/2 min. A 2- by 6-in. board wrapped inside several folds of membrane was placed in a shallow ditch at the top of the slope, then secured with six drive tack anchors, and covered with excavated soil. This phase of the entire procedure, depicted in Photo H5, required an additional 10.5 min. The elapsed time was 19.5 min.

18. In the initial test with the M113 APC, the driver of the vehicle experienced difficulty in aligning the vehicle with the membrane-covered slope. As the driver maneuvered the vehicle into position for the slope-climbing test, the vehicle pressed the 18-ft-wide membrane down into the soft lake bottom, pulling the membrane edges and sandbags to a point adjacent to the tracks of the vehicle. As the vehicle attempted to climb the slope, the membrane and sandbag ropes became entangled in

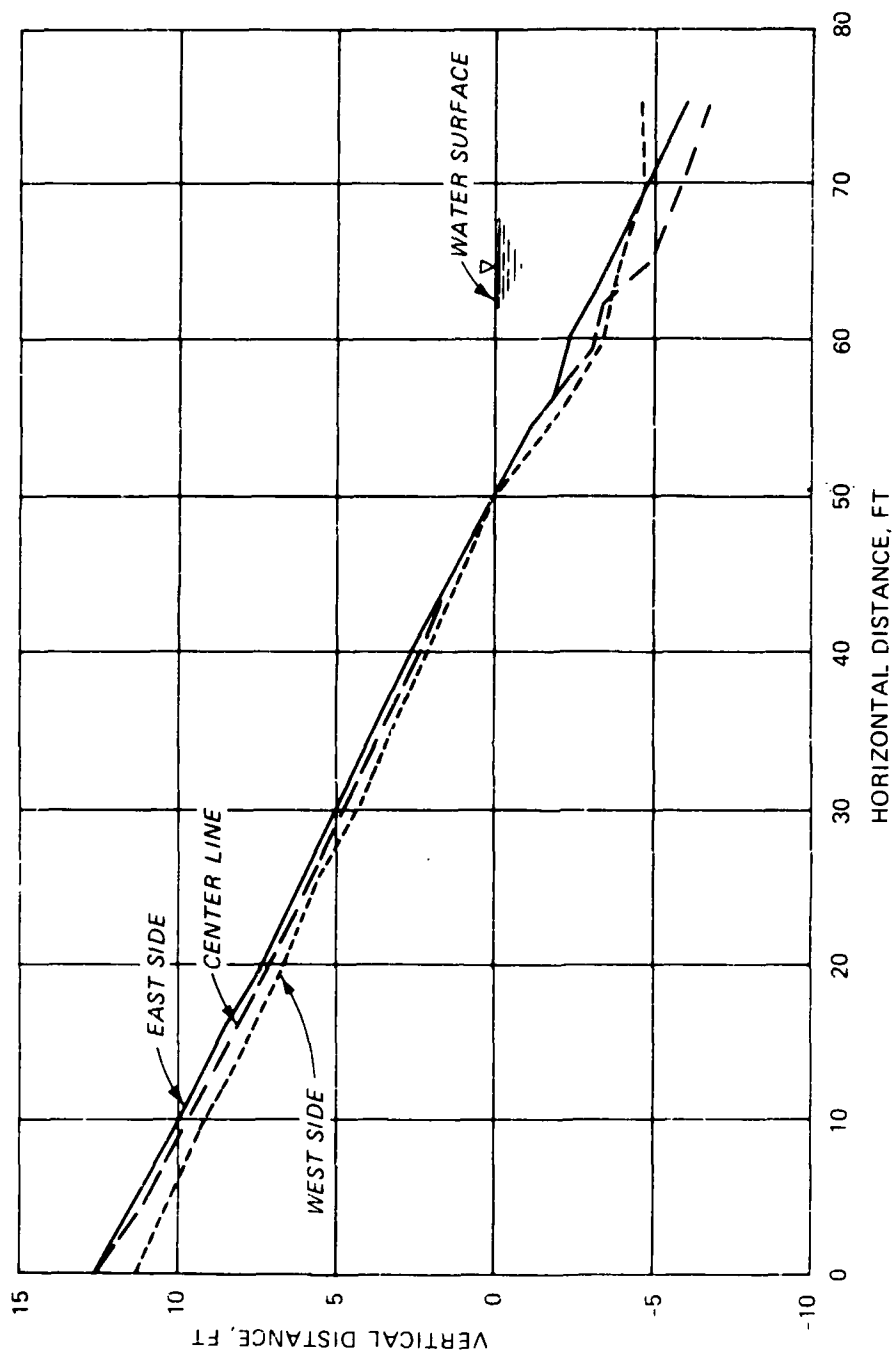


Figure H2. Before traffic profile, Brown Lake slope

the left track, pulling the membrane down the slope toward the water. The slope side anchors tore the membrane 12 to 15 ft, and the 2- by 6-in. anchor board was pulled 10 to 12 ft downslope. The vehicle continued upslope with the membrane severely stretched and wrinkled as shown in Photos H5i-H5k.

19. Analysis of the first lake tests on the membrane-covered slopes indicated that (a) the short 1-ft-long anchors were not of sufficient length to prevent downslope sliding of the membrane, (b) the membrane, by necessity, required additional anchoring at the top of the slope, (c) a fold of membrane was required near the water's edge and the membrane pad should be wider, both to allow for conformation to the vehicle ruts in the lake bottom, and (d) the sandbag anchors, by necessity, should be tied to a small steel cable and placed at least 20 ft from the membrane edge. Accordingly, all of these suggestions were incorporated into the second membrane test.

20. A larger membrane section, 36 by 100 ft, was refolded and delivered to the lake site. The unfolding procedure used previously was again employed, except the placement of the membrane from the top down the slope required five men a total of 35 sec to complete. A ditch approximately 3-1/2 ft wide by 2 ft deep by 25 ft long was excavated with a hydraulic backhoe. The membrane was placed along the perimeter of the ditch and secured with seven 1-ft anchors evenly spaced along the inside of the 25-ft ditch. The ditch was filled with the excavated soil and side anchors were placed along the edges of the membrane section at 10-ft intervals. A 4-ft fold was left in the membrane section at the water's edge, and the remainder of the membrane was pulled out into the lake and anchored using the M113 APC and a boat, each with two men aboard. Steel cables, 20 ft long, were attached to the membrane and to sandbags dropped into the water perpendicular to the membrane length to secure the membrane section and prevent floating or limited lateral movement. Photos H6a-H6f depict this procedure.

21. The M113 APC entered the lake and swam around to a position in the lake aligned with the membrane on the slope. On the initial pass, the M113 APC was able to place both tracks up onto the membrane

section after pulling the 4-ft fold of the membrane section into the lake. However, the vehicle was not able to climb completely out of the lake. The vehicle backed out into the lake and aligned for a second attempt. A small tear in the membrane was noted at the water's edge. On the second attempt, the membrane tore and shredded in numerous places under the vehicle tracks. While maneuvering into position for a third attempt to climb the slope, the driver noted that the left running gear was inoperative. The vehicle was turned around into a position that facilitated removal from the lake. The vehicle was then pulled out of the lake and up the slope by the M48 tank. As soon as the M113 APC exited the water, the reason for immobilization was readily apparent. Some six to eight wraps of T17 membrane had been pulled around the sprocket between the sprocket and tracks. The rolled membrane thickness had forced the track away from the sprocket, thereby immobilizing the vehicle (Photos H6g-H6n). In addition, one of the cables used to anchor the sandbags was entangled in the track. The exact cause of the entanglement, however, could not be determined. After the M113 APC was repaired, several unsuccessful attempts were made to exit the lake up the 25 percent slope (Photos H6o-H6r). However, the M113 APC could only exit the lake at the prepared ramp (Photo H6s) where the slope was less than 15 percent.

22. Analysis of the T17 test results indicate several problem areas relative to the membrane section tests: (a) membrane edges in turbulent water are subject to entanglement in the vehicle running gear, and ropes or cables attached to the membrane as anchors may increase the risk of such entanglement; (b) vehicle tracks push the membrane into the lake bottom, thereby creating a slippery surface at the water's edge, which may also contribute to vehicle slope-climbing problems; and (c) time and equipment needed to anchor and place the membrane exceed the LOA requirements.

23. M8A1 mat-covered slopes. Slope-climbing tests were conducted on the same 25 percent slope used in the membrane test described previously, but in these tests the slope was covered above and/or below the water's edge with the M8A1 mat. The mats were connected in the normal

manner, hooks downslope and perpendicular to the slope (across the slope width), to form parallel "runs" 18 in. wide composed of interconnected mat pieces. Initially, 5 runs were placed across the slope itself, and 11 runs were placed parallel to these runs but underwater beginning at the water's edge. The mat was anchored on the slope with four screw-type anchors (Photos H7a-H7f).

24. In the initial vehicle test on a dry slope, the M113 APC entered the lake and maneuvered into position to climb the slope. The vehicle attempted to climb the slope five times without success (Table H1). The mat surface apparently had an insufficient traction surface for the vehicle track system as the vehicle merely spun its tracks on the mat with no forward movement (Photos H7g-H7i).

25. For test No. 2, 16 runs of mat were pulled up the slope and flipped over with a crane so that the support ridges on the bottom of the mat were facing upward, i.e., the mat was inverted relative to its normal placement condition. Ten runs of mat were pushed into the water by a bulldozer, and six runs were left on the slope. The mat was not anchored at the start of the test. The vehicle entered the lake and maneuvered into test position. The vehicle then eased up onto the mat, touching some 15 ft or so out into the water, and by very slowly moving forward was able to exit on the slope in the second attempt. The support ridges on the mat created tractive surfaces such that the cleats on the track system were able to gain sufficient support for the vehicle to complete one pass with difficulty, a very marginal single pass. However, the vehicle pushed 3 runs of mat into the water, leaving 3 runs upslope and 13 underwater. Consequently, the test was continued with 3 runs upslope, 13 in the water, and the mat anchored with the rolled edge of the mat downslope to determine any advantage of having more mat in the water (Photo H8).

26. Five attempts at passage were made by the vehicle from the water with 3 runs upslope and 13 underwater, but only two passes were completed (Table H1) with the mat surface dry. The test was temporarily halted when the cables slipped and the mats moved completely into the water, pushed there by the track system pulling downslope on the mat

when gaining traction. Therefore, the mat was reanchored by cable to the ground with the first mat at the water's edge. Three anchors were placed in the slope on each side of the mat and tied together with cable. The mat was inverted with the rolled edge of the mat downslope, and the test continued.

27. The vehicle entered the lake and swam around into position for the next pass of traffic. The vehicle eased up onto the mat, and after several spinning attempts, the vehicle was able to complete one pass up the dry mat and slope. However, the mat was pulled completely into the water. Testing was continued, and the vehicle completed 26 passes without much difficulty, although the vehicle tracks spun to varying degrees upon contact with the mat. At the end of test No. 2, the mats had moved into the lake such that the first mat (toward the slope) was 18 in. out from the water's edge. The driver of the vehicle developed a swimming-climbing technique, which improved vehicle performance in the latter half of the passes. The vehicle needed a higher gear (third) for better water speed and maneuverability but a low gear for slope climbing. Accordingly, the driver would reach full speed (3-5 mph) in the water in third gear while moving toward the slope; then immediately prior to mat contact, he would downshift to low gear. At the moment of contact, the driver would then accelerate onto the mat and continue upslope. This procedure seemed to push the vehicle onto the mat by inertia and weight transfer, and the shift to low gear then increased the traction capability of the vehicle upslope on the mat and slope (Photos H9a-H9l).

28. For test No. 3, 16 runs of mat were left in position (after the previous tests), and the slope was sprayed with water from a truck. The M113 APC had little difficulty completing 15 passes before being stopped because of anchor failure on the left side. After the anchor was repaired, tests were continued; the vehicle completed 3 more passes (total of 18) without much difficulty (Photos H9m-H9r). However, it was discovered that the first 5 runs of mat at the water's edge had been disconnected from the other 11 runs, which had been pushed farther out into the lake. The five panels were removed from the lake by crane and were

heavily damaged by vehicle traffic, especially at the panel joints (Photo H10). Evidently, the rolled edge, when placed downslope, was rather easily opened up and unrolled by the track system spinning on the rolled section. After unrolling, the panels then easily disconnected with little effort.

29. Two runs were replaced in the water (though not attached to the 11 runs already in the water) about 2 ft from the water's edge and anchored to the slope. The slope was again sprayed with water from a water truck to simulate a rainy or surface slipperiness condition on the slope and traffic continued. The vehicle had difficulty getting onto the mat at first, but after apparently seating the mat in the lake bottom, the vehicle completed 5 passes (total of 23) without difficulty before anchor failure occurred on the left again. The mat was reanchored, and 2 more passes were made to complete the required 25 passes to conclude test No. 3.

30. The slope was checked for test No. 4, and negligible change was noted. The panels of mat were retrieved from the water, and five runs were reconnected with the top side up. The mats were then shoved into the water a distance of 4 ft from the water's edge and anchored. The rolled edge was downslope, and the slope was continuously sprayed with water during traffic. The vehicle attempted to climb onto the mat but could not gain sufficient traction to exit the water. The tracks would catch momentarily on the connector hooks of the mat but could not develop sufficient traction; thus spinning and backsliding occurred. Five attempts were made at passage with no success (Photos H11a-H11e).

31. The five runs of mat were then pulled from the lake, inverted (by crane) with the hooks downslope, and anchored and replaced underwater some 2.5 ft from the water's edge for test No. 5. The slope was sprayed with water prior to and during testing. However, in five attempts at passage, the vehicle was not able to complete a single pass. In test No. 6, the mat was pushed farther into the water so that the first panel was 4 ft from the water's edge. In four attempts, the vehicle was still unable to complete a single pass although both slow- and fast-speed runs were attempted (Photo H11).

32. The five runs of mat were removed from the lake by crane and replaced with two runs of mat about 4 ft into the lake for test No. 7. The slope was again sprayed with water to simulate wet-season conditions. The vehicle made the first approach at full speed, and upon encountering the mat underwater, the vehicle appeared to "seat" the mat into the lake bottom, then override the mat and continue upslope. After two passes, the mat had been pushed out into the lake another 2 ft. The vehicle was able to complete 8 passes in 10 attempts with little difficulty. However, the left-side anchor became loose, and the test was stopped. The relative ease of the slope climbing of the vehicle in the 8 passes indicated that the vehicle could complete the required 25 passes with little difficulty, and so this test was stopped (Photos H11g-H11h).

33. For test No. 8, two runs of mat were placed in the lake in the original configuration, i.e., surface up, but with the rolled edge the farthest out in the water, approximately 4 ft from the water's edge. The surface of the slope was left dry. The vehicle was able to complete 9 passes in 11 attempts with high slippage and poor control (Photos H11m-H11q). Analysis of the test results indicated that the overlap edge (hook) may have provided sufficient traction to complete the required passes. However, it appeared that the slope had been decreased by traffic at the water's edge and may have aided the vehicle passage. Reprofiling of the slope (Figure H3), however, did not show any large slope changes.

34. In summary, the M8A1 mats provided the vehicle somewhat marginal assistance in exiting the lake. However, unless placed in exactly the right position and anchored securely, the vehicle was unable to utilize the mats. Also, the mat (and membrane) required rather long periods of time for placement, more on the order of 2 to 3 hr or more, rather than the 15 min or less that was desired. Wetting the slope did not appear to hinder vehicle passage to any great degree in these tests, although clay slopes may produce slippery conditions more so than those experienced in these tests. Differences in soil strength as determined from the average of cone index measurements before and after traffic (Figure H4) were not significant.

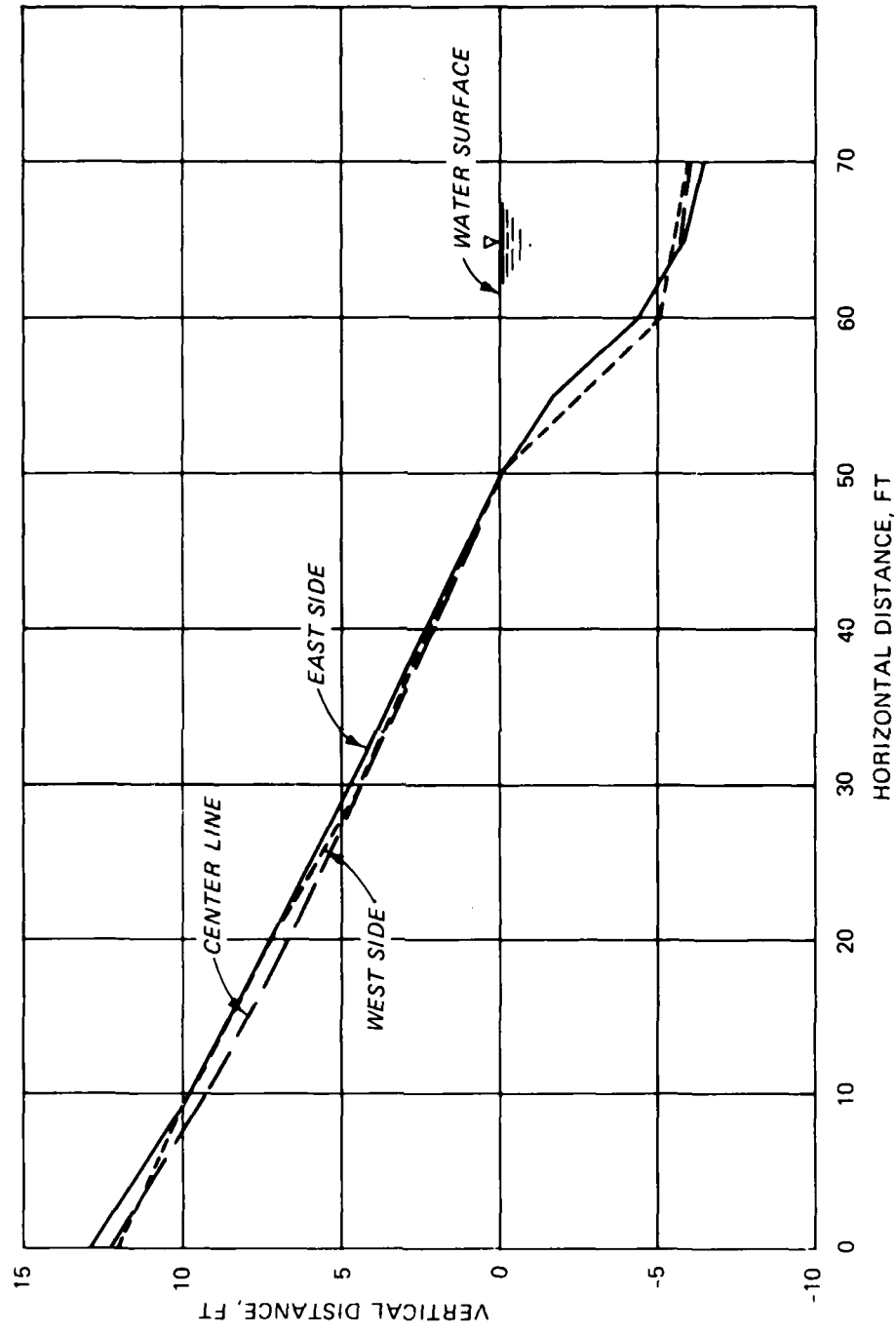


Figure H3. After traffic profile, Brown Lake slope

Meas. No.	Cone Index Depth, in.										
	SFC	1	2	3	4	5	6	9	12	15	18
<u>Before Traffic</u>											
1	70	170	250	240	300	230	230	250	650	750+	750+
2	140	200	200	200	185	180	225	310	400	350	340
3	140	260	250	270	290	330	370	420	530	600	750+
4	130	190	175	160	190	190	215	720	750+	750+	750+
5	150	170	150	180	300	230	300	330	300	220	220
6	130	170	150	140	140	125	185	300	250	220	210
7	260	350	340	260	240	300	270	250	180	170	250
8	170	270	340	420	320	240	240	230	200	210	300
9	120	250	330	410	330	290	280	250	320	280	250
10	170	180	180	160	200	230	270	260	330	330	410
Avg	148	221	236	244	250	234	258	332	391+	388+	423+

Average Cone Index by Depths, in.: 0-6 = 236; 6-12 = 326+; 12-18 = 438+

<u>After Traffic</u>											
1	50	150	210	240	300	230	230	250	475	600	750+
2	110	170	200	270	300	180	220	255	440	570	550
3	125	200	250	290	330	190	220	320	500	720	750+
4	120	200	270	320	285	230	245	325	450	560	600
5	130	190	280	300	270	230	260	370	580	750+	750+
6	125	210	220	270	290	250	270	330	250	220	250
7	150	230	300	300	320	240	265	345	320	280	340
8	140	240	340	320	330	300	340	470	430	330	410
9	120	180	320	310	290	265	240	305	180	210	250
10	120	210	260	190	240	250	285	340	260	170	210
Avg	119	198	265	281	296	236	258	331	388	441+	486+

Average Cone Index by Depths, in.: 0-6 = 236; 6-12 = 326; 12-18 = 438+

Figure H4. Before and after traffic cone indexes
for 25 percent slope, Brown Lake

Drawbar pull tests

35. A firm, dry, level grass-covered area within the boundaries of the WES reservation was selected for drawbar pull tests (Photo H12) using an M113 APC partially loaded to 19,950 lb. The area was 100 percent covered with Bermuda grass atop silty clay soil. The vehicle was instrumented for the tests, and a 20,000-lb load cell was connected by cables to a loaded M113 APC. Only maximum pull values and pull values at 100 percent slip were measured.

36. Initially, a vehicle test was conducted on dry grass as an in situ condition. The vehicle was able to develop 13,922 lb of drawbar pull during the test as a maximum and 13,200 lb at a 100 percent slip. These values correspond to drawbar pull coefficients (drawbar pull, lb ÷ vehicle weight, lb) of 0.70 and 0.66, respectively.

37. A 36- by 100-ft membrane pad was next unrolled, stretched, and staked at the sides and ends with anchors. The test was conducted dry as in the dry grass tests. The vehicle was able to develop a maximum of 13,287 lb with 10,494 lb at 100 percent slip, corresponding to drawbar pull coefficients of 0.67 and 0.53, respectively. In this test, the membrane stretched and wrinkled beneath the tracks at the high-pull values but returned to almost the original position after traffic. The membrane material around the anchors also tore in the direction of pull, especially during the high-pull portion of the test.

38. The membrane was sprayed with water from a water truck continually during the next test series on wet membrane. The pull was reduced considerably to 7109-lb maximum with only 4062 lb at 100 percent slip, or drawbar pull coefficients of 0.36 and 0.20, respectively. Membrane stretching and wrinkling occurred as in the dry membrane tests. The tracks were then sprayed while the membrane was wet to simulate water existing from a lake or river with similar pulls and coefficients as the previous tests at a maximum of 7024 lb (0.35) with 3980 lb (0.20) at 100 percent slip.

39. The membrane was removed and the grass sprayed for the next test series. On the wet grass, the vehicle developed a maximum of 7363 lb (0.37) with 7363 lb (0.37) at 100 percent vehicle slip. The

vehicle was towed in neutral gear for the motion resistance measurement, which averaged 1875 lb (0.094) for these tests.

40. As shown in these tests, the dry membrane reduced the maximum pull obtained by the M113 APC in dry grass less than 20 percent, but this reduction increased to about 60 percent from dry, when the membrane was wet, although the wet grass also reduced the pull from that at the dry grass condition by almost this amount. However, using the usual assumption that the drawbar pull coefficient is approximately equal to the slope in percent for tests in firm soils, the M113 APC should be able to climb a maximum wet membrane-covered slope of 20-35 percent. This assumption coincides with the results of the lake tests in which the slope-climbing capability of the M113 APC was rather marginal on 23-25 percent slope at Brown Lake.

Summary of Test Results and Recommendations

Summary of test results

41. Results of this study are summarized below:

- a. Tests with T17 membrane-covered slopes (25 percent or less) in upland areas and adjacent to a lake indicate that the membrane must be anchored extremely well on the slope and that the membrane itself does not necessarily assure traction at the toe of the slope at the water/soil interface. When wet, the membrane becomes relatively slick but still produces a sufficient traction surface for vehicle passage, provided the vehicle can negotiate the slope.
- b. Tests on mat-surfaced slopes (M8A1 or M19) indicate the same problems that were encountered in the membrane tests. When the mat was moved totally underwater, the vehicle negotiated the slopes, sometimes easily and other times marginally, depending on the mat configuration and the presence of any points on the mat for the vehicle to gain sufficient traction to climb the slope. The vehicles negotiated the mat-covered slopes rather easily, wet or dry, when sufficient traction was obtained to climb the slope.
- c. Placement times of 15 min were not achieved. In fact, placement of the membrane or mat on riverbanks or slopes by any of the means used in the tests requires at least twice the time stated in the LOA. Also, engineer

equipment must be available for anchor placement, mat placement upside down on the slope, and mat or membrane anchorage underwater.

- d. Membrane placed in lake bottoms underwater must be placed so that allowances are made for the membrane movement to conform to vehicle ruts in the soft lake-bottom mud and the edges are anchored to the lake bottom to prevent entanglement in vehicle running gear. Cables attached to sandbags that were used to anchor the mat to the lake bottom in the tests reported herein became exposed with vehicle traffic and were easily entangled in the vehicle traction elements.
- e. The M113 APC was able to exit the lake at an unimproved soil ramp where the slope was less than 15 percent. The slope that represents its limiting capability is unknown.

Recommendations

42. Of the currently available depot items, which were considered for evaluation as a surfacing of a slope used in an egress mode, the following recommendations are warranted:

- a. The T17 membrane, M19 mat, and M8A1 mat, when placed in normal placement patterns, will not support significant traffic on a 25 percent slope, primarily because of inadequate traction (coefficient of friction).
- b. Although the M19 and M8A1 mats will provide structural support to both wheeled and tracked vehicles on 25 percent slopes and less when dry, the membrane is torn and is not effective if used alone.
- c. To achieve the necessary traction required on a 25 percent slope, especially when mud is tracked on the slope surface, it appears that the M8A1 mat must be placed with the bottom side (ribs) up for tracked swimmers, such as the M113 APC. However, this placement will not meet the LOA because its placement-time requirements far exceed those of the LOA.
- d. A surfacing should be developed that would provide the necessary structural strength for the tactical vehicles as well as the necessary tractive surfacing to allow climbing the 25 percent slope in a muddy environment.
- e. Where egress improvement is desired and the stringent time, manpower, and equipment limitations of the LOA are not present, expedient methods are available. One method would be to flatten the slope using a D-7 bulldozer or use the combat engineer vehicle (CEV). The other is the inverted M8A1 installation described in c. above.

Table H1

Summary of Tests of the M8A1 on 25 Percent Slope, Brown Lake

Test	Attempts	Passes	Mat Surface Up/Down	Mat End in Water 1st	Distance from Water's Edge to 1st Mat,* ft	Slope Condition	Remarks
1	5	0	Up	Hook	NA**	Dry	11 runs in water, 5 runs on slope
2	2	1	Down	Rolled	NA	Dry	10 runs in water, 6 runs on slope
	5	2	Down	Rolled	NA	Dry	13 runs in water, 3 runs on slope
	31	26	Down	Rolled	NA	Dry	After 3 passes, all mats in water, and after 8 passes, all mats 18 in. in water
3	15	15	Down	Rolled	1.5	Wet	16 runs in water
	19	18	Down	Rolled	1.5	Wet	Anchor failed. Bank 5 runs disconnected from 11 runs. Half panel loose in 5 runs. Replaced with 2 runs in water
	28	25	Down	Rolled	2.0	Wet	
4	5	0	Up	Rolled	4.0	Wet	5 runs
5	5	0	Down	Hook	2.5	Wet	5 runs only. 2 slow and 3 fast attempts
6	4	0	Down	Hook	4.0	Wet	Slow and fast speed
7	10	8	Down	Hook	4.0	Wet	2 runs only. After 2 passes, mat 6 ft in water
8	11	9	Up	Rolled	4.0	Dry	2 runs only. Poor control of vehicle

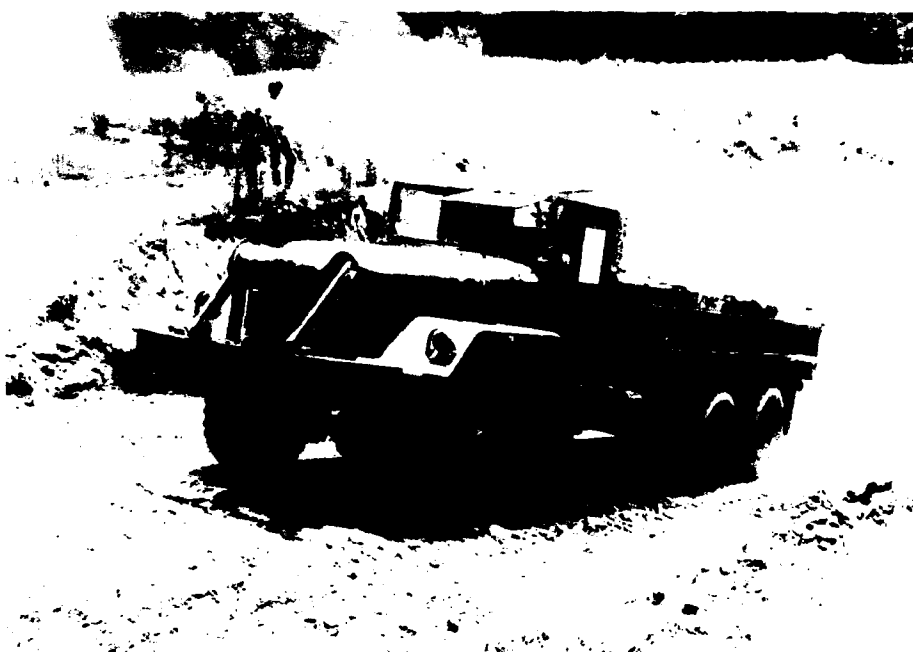
Note: In the last test, the slope in and near the water had probably decreased because of traffic.

* Other mats were farther out in the water.

** Not available.

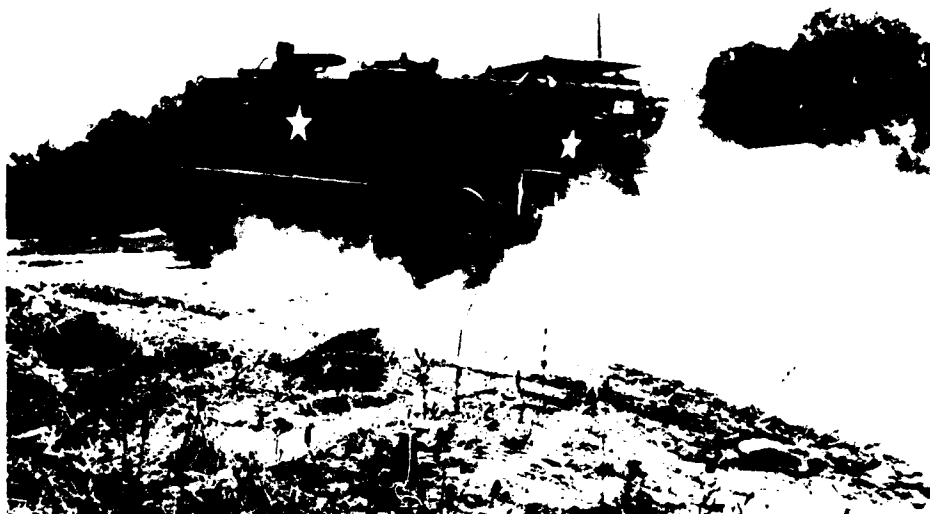


a. Dry slope



b. M54 truck completing 25 passes on dry slope

Photo H1. Unsurfaced 25 percent slope test area (Sheet 1 of 4)



c. M113 APC completing 25 passes on dry slope



d. M48 tank on dry slope

Photo H1. (Sheet 2 of 4)



e. M54 truck attempting to travel up the wet slope



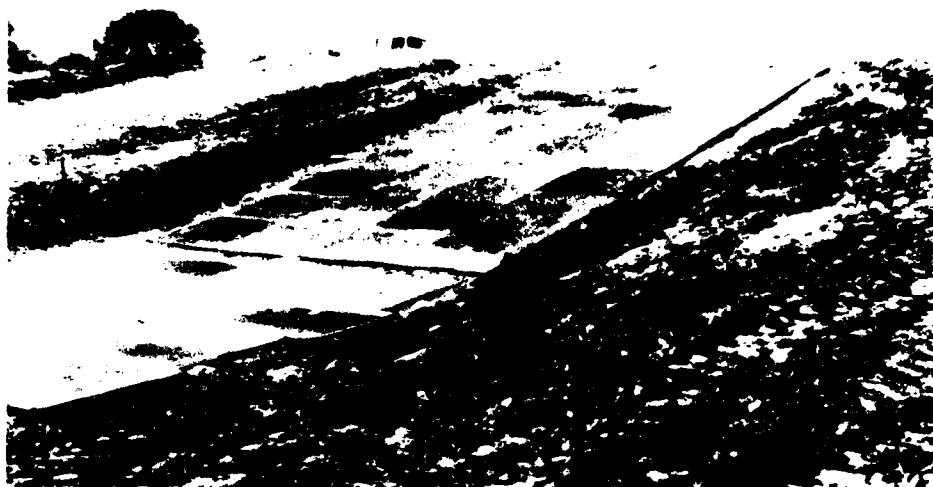
f. M113 APC attempting to travel up the wet slope

Photo H1. (Sheet 3 of 4)



g. M48 tank attempting to travel up the wet slope

Photo H1. (Sheet 4 of 4)

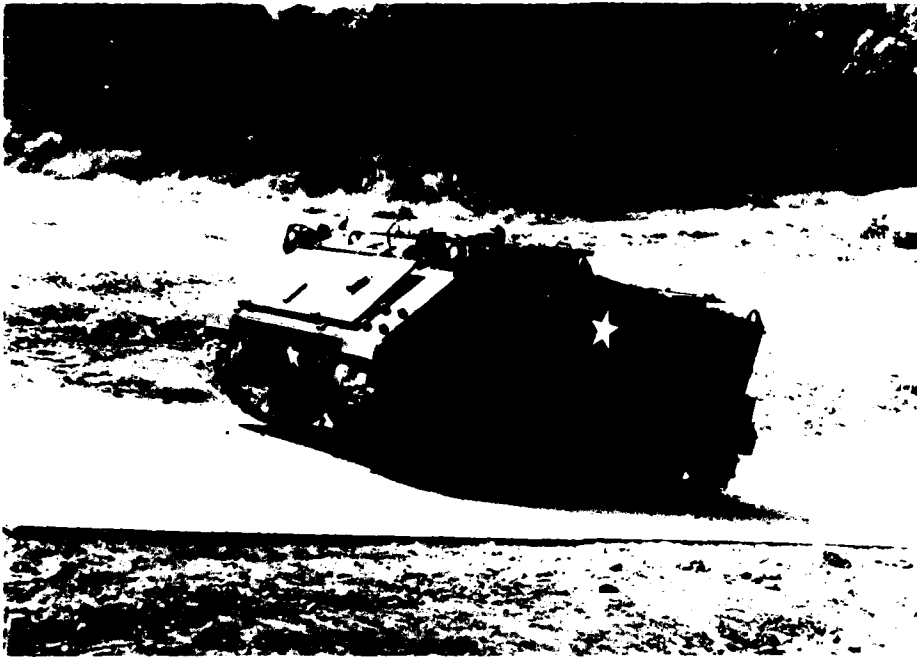


a. M19 surfacing on 25 percent test slope



b. M54 truck making initial pass on dry mat slope

Photo H2. Twenty-five percent test slope area surfaced with the M19 mat (Sheet 1 of 2)



c. M113 APC making 25 passes on dry mat slope



d. M48 tank making initial pass on dry mat slope

Photo H2. (Sheet 2 of 2)

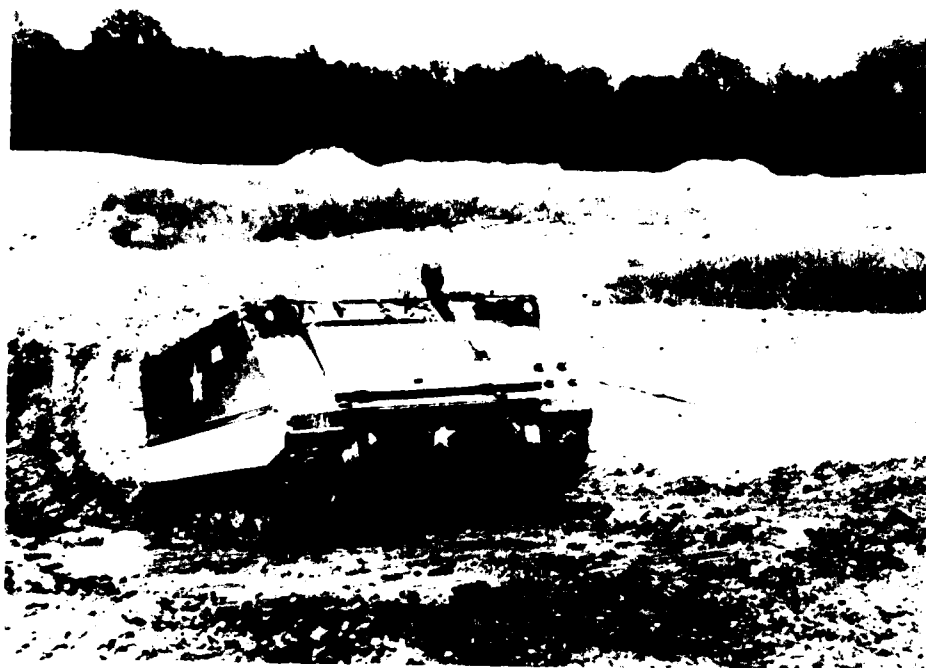


a. M54 truck attempting to make a pass up the slope



b. M48 tank attempting to make fourth pass up the slope

Photo H3. Traffic on 25 percent slope surfaced with M8A1 mat, wet, after exiting wet clay soil at toe of slope (Sheet 1 of 2)



c. M113 APC making one of 25 passes up the slope

Photo H3. (Sheet 2 of 2)



a. View of membrane movement on dry slope with traffic by the M48 tank

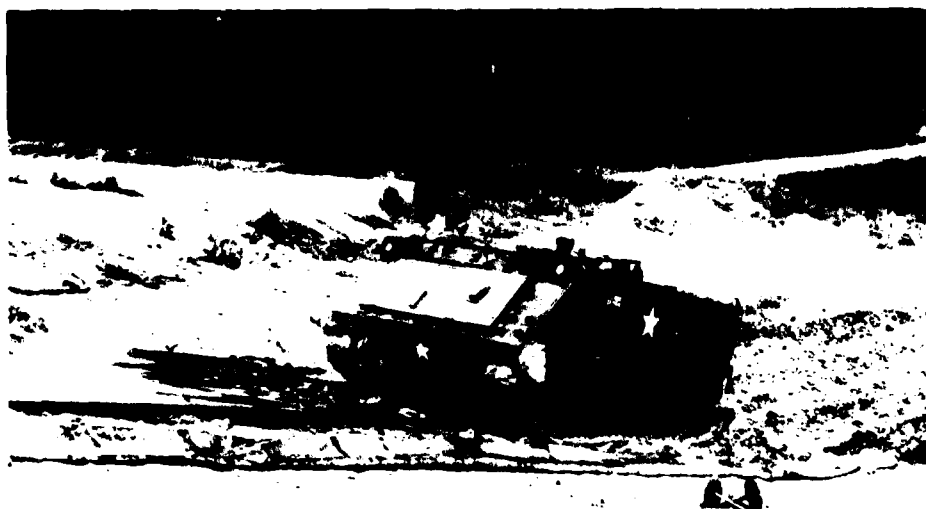


b. View of membrane and dry slope after vehicle traffic

Photo H4. T17 membrane-covered slope tests, upland areas (Sheet 1 of 5)

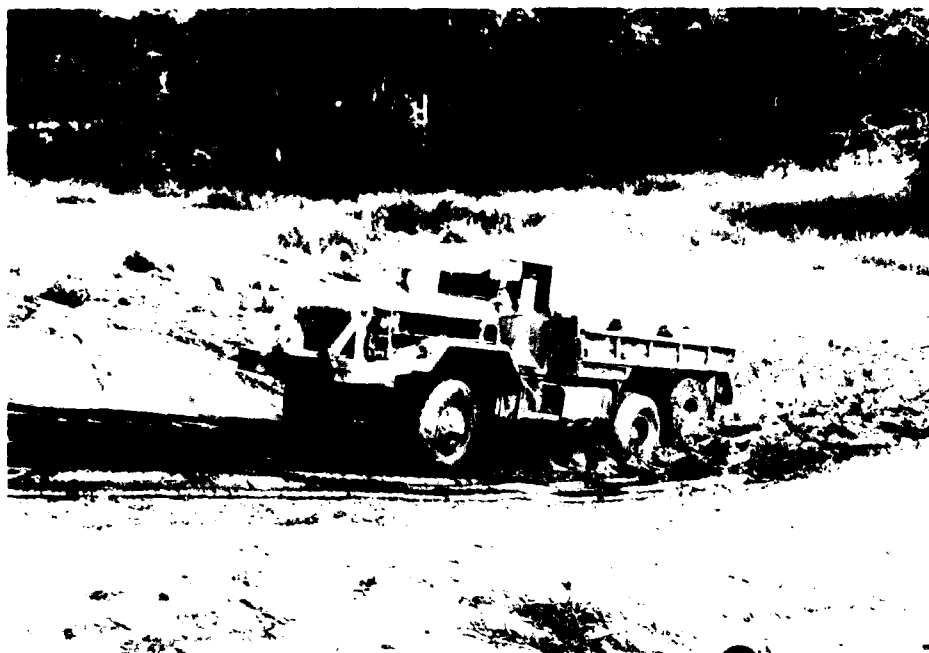


c. View of replaced and tacked membrane prior to vehicle traffic on the wet slope

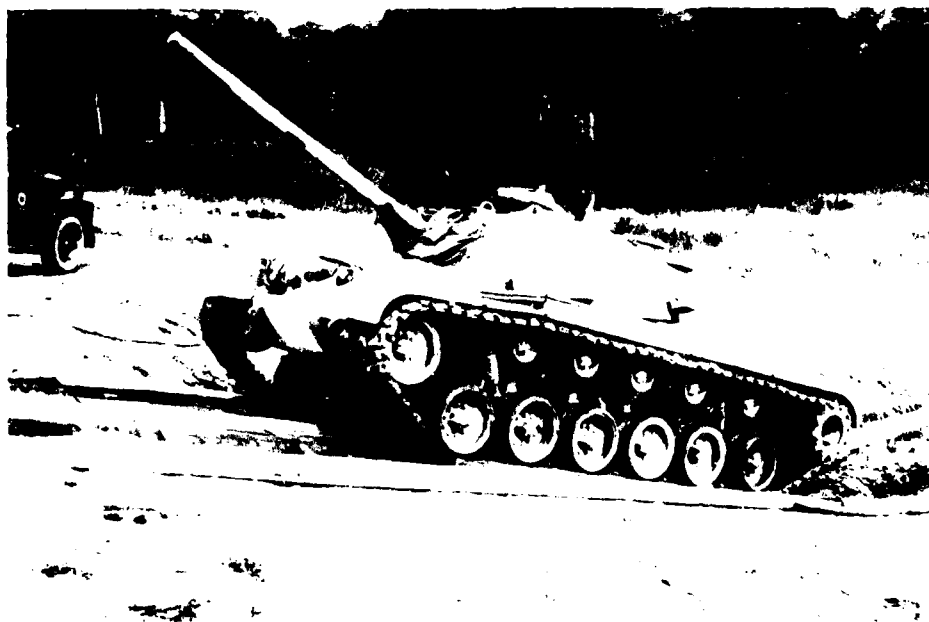


d. M113 APC attempting to negotiate 25 percent membrane-covered slope while slope is wet

Photo H4. (Sheet 2 of 5)



e. M54 truck attempting to negotiate a wet 25 percent membrane-covered slope with a wet clay layer at toe of slope



f. M48 tank attempting to negotiate a wet 25 percent membrane-covered slope with a wet clay layer at toe of slope

Photo H4. (Sheet 3 of 5)



g. M113 APC stretching and tearing a wet membrane-covered slope



h. View of membrane stretching at the membrane-clay layer interface

Photo H4. (Sheet 4 of 5)



i. View of membrane-covered slope after all traffic tests completed

Photo H4. (Sheet 5 of 5)



a. Slope indicator showing 25 percent slope



b. View of folded membrane as delivered to slope site

Photo 1. T17 membrane-covered slope tests,
Brown Lake area (Sheet 1 of 6)



c. Lateral unfolding procedure to place membrane across slope



d. Stretching of membrane upslope prior to anchoring

Photo H5. (Sheet 2 of 6)



e. Membrane placement into lake underwater

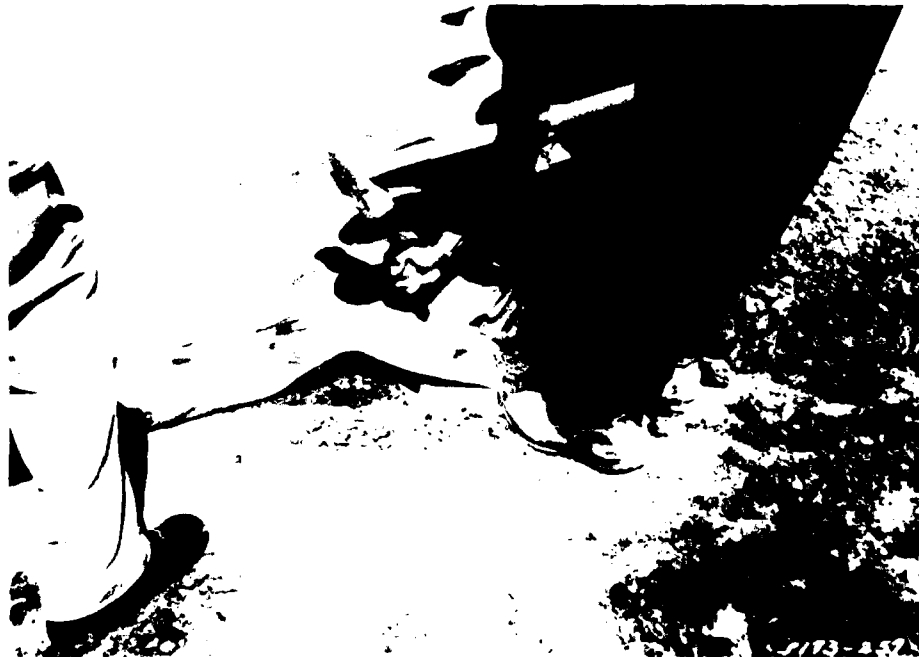


f. Cable and sandbag anchoring of membrane in lake

Photo H5. (Sheet 3 of 6)

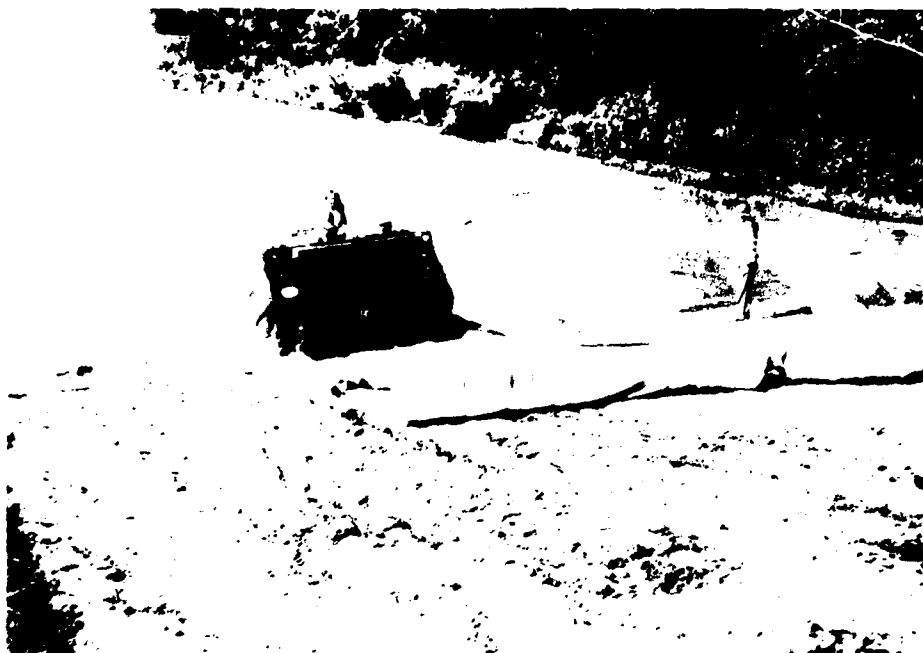


g. Small trench at top of slope used to anchor membrane folded around 2- by 6-in. board



h. Anchor placement on membrane at 2- by 6-in. fold

Photo H5. (Sheet 4 of 6)



i. Initial slope-climbing test with the M113 APC
showing membrane pulled downslope



j. Sandbag/cable and membrane wrapped up in
vehicle track system

Photo H5. (Sheet 5 of 6)



k. Membrane position and condition at end of test

Photo H5. (Sheet 6 of 6)



a. Folded 36- by 100-ft T17 membrane as delivered to top of slope



b. Lateral unfolding of membrane across width of slope

Photo H6. T17 membrane-covered slope tests (w/fold),
Brown Lake area (Sheet 1 of 10)



c. Pulling of membrane downslope prior to anchoring



d. Ditch, 3-1/2 by 2 by 25 ft, excavated at top of slope for membrane anchoring

Photo H6. (Sheet 2 of 10)



e. Side anchor placement by manual labor



f. Sandbag anchor placement in water by boat (note the 4-ft fold left in membrane at water's edge)

Photo H6. (Sheet 3 of 10)



g. Initial vehicle contact with underwater membrane showing unfolding of 4-ft fold at water's edge



h. M113 APC attempting to climb onto membrane on slope

Photo H6. (Sheet 4 of 10)



i. M113 APC almost up out of water and onto slope



j. Vehicle sliding back into water after spinning on membrane

Photo H6. (Sheet 5 of 10)



k. Damaged membrane shredded at water's edge by spinning tracks of vehicle



l. Vehicle immobilized by membrane entangled in track system

Photo H6. (Sheet 6 of 10)



m. Vehicle being pulled from lake, showing damage to left sprocket



n. Membrane entangled in left sprocket (note steel anchor cable in sprocket, which may have caused initial entanglement)

Photo H6. (Sheet 7 of 10)

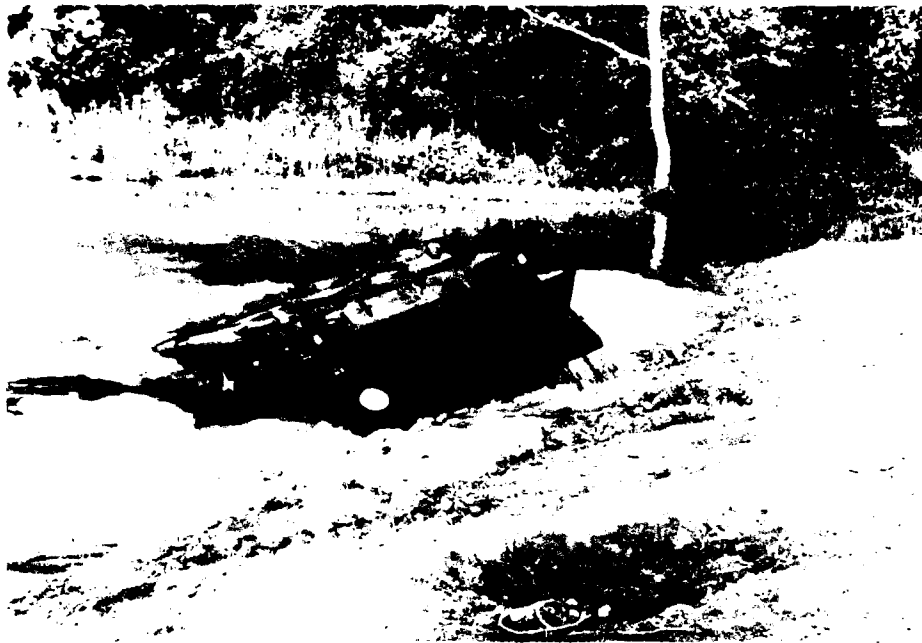


o. After repair vehicle attempted to climb unsurfaced slope



p. Vehicle just climbing onto base of slope at water's edge

Photo H6. (Sheet 8 of 10)



q. Vehicle tracks spinning on slope at water's edge



r. Vehicle attempting to climb slope at an angle
to slope center line

Photo H6. (Sheet 9 of 10)

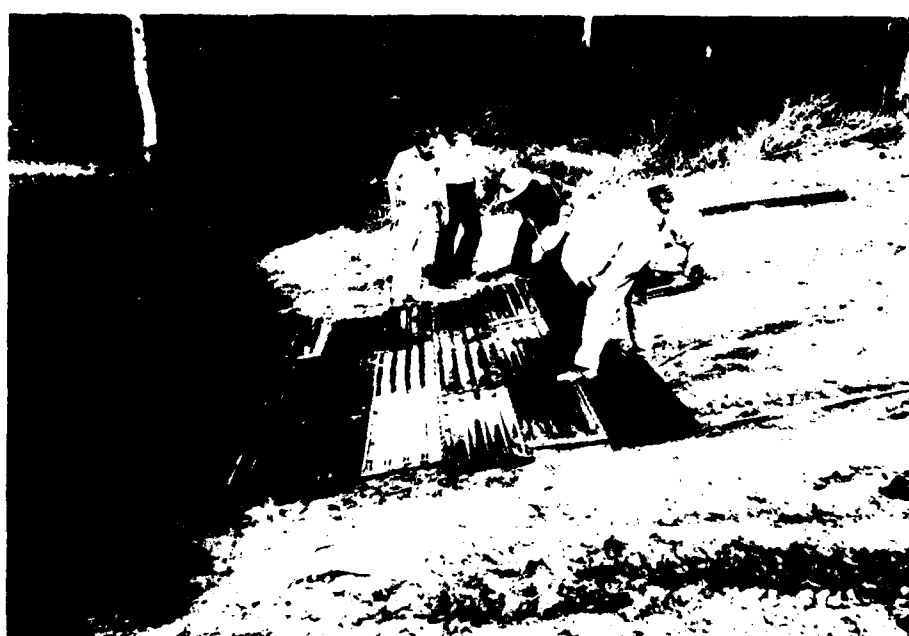


s. Vehicle exiting lake at ramp constructed earlier

Photo H6. (Sheet 10 of 10)



a. Placement of mat, right side up on slope



b. Mat slid into lake and additional sections added on slope

Photo H7. M8A1 mat-covered slope tests, Brown Lake area
(Sheet 1 of 5)



c. Mat sections being dragged by cable into lake

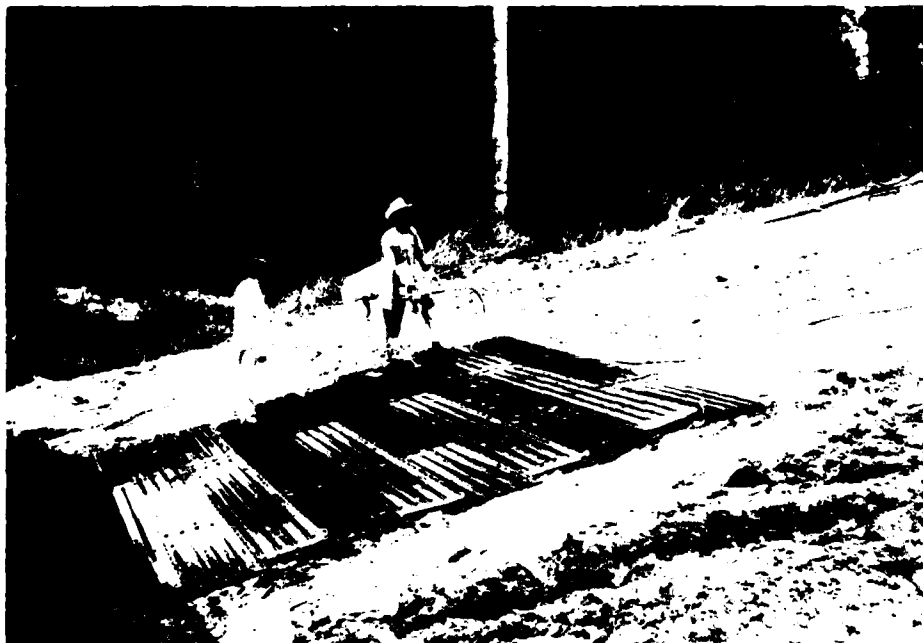


d. Mat sections on slope and in lake prior to anchoring

Photo H7. (Sheet 2 of 5)



e. Anchor placement to prevent downward sliding into lake



f. View of final anchor placement prior to tests

Photo H7. (Sheet 3 of 5)

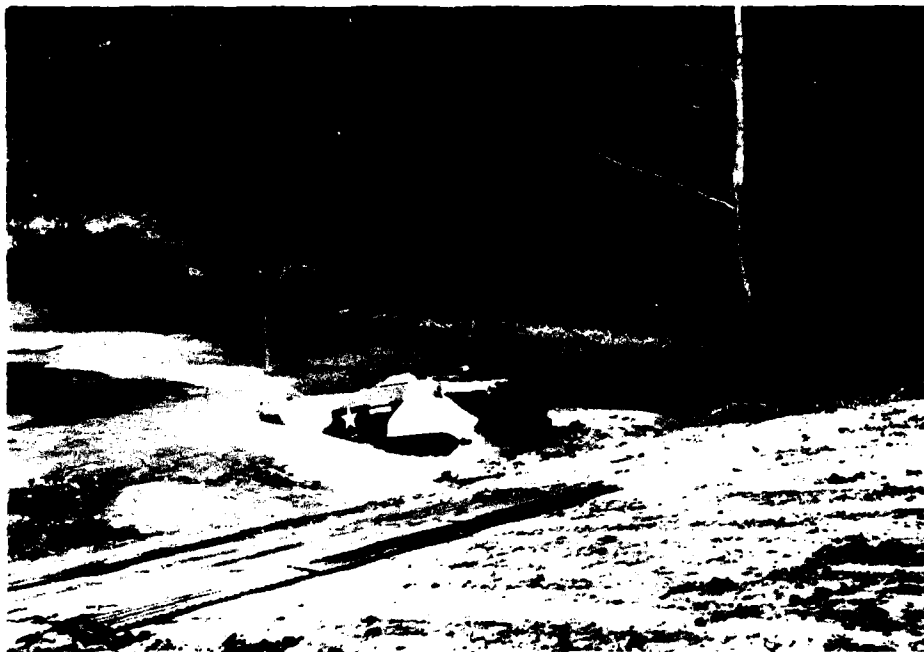


g. Initial vehicle test on mat, right side up



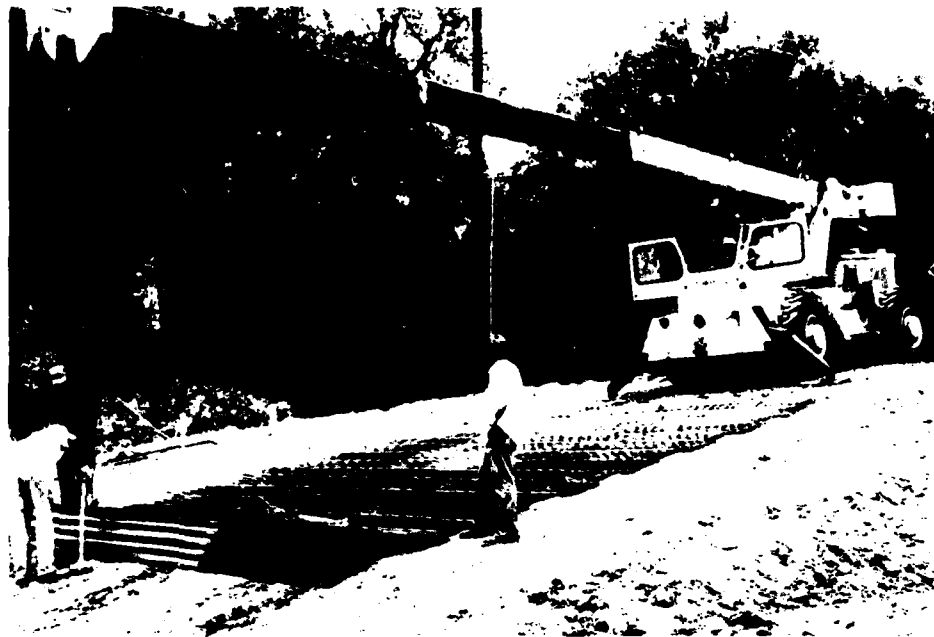
h. Vehicle attempting to climb onto mat but tracks spinning

Photo H7. (Sheet 4 of 5)

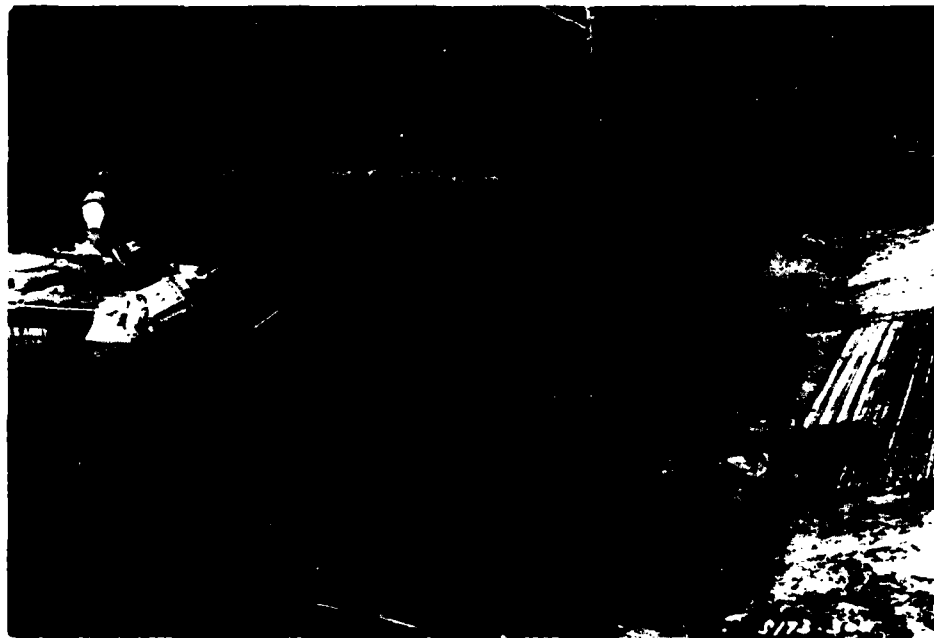


i. Test conducted on unsurfaced slope without success

Photo H7. (Sheet 5 of 5)

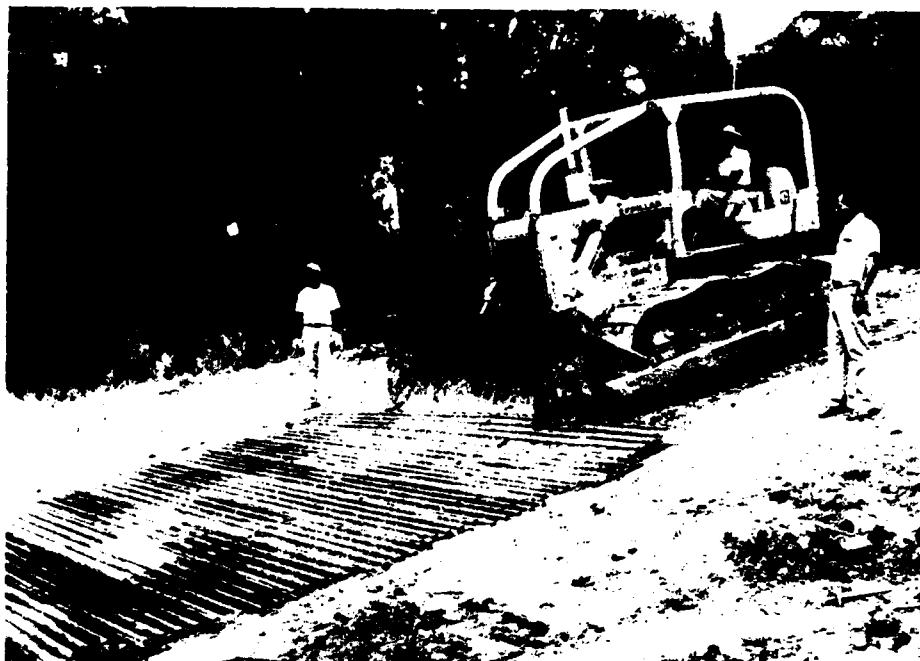


a. Mat sections inverted to expose raised ridges on bottoms

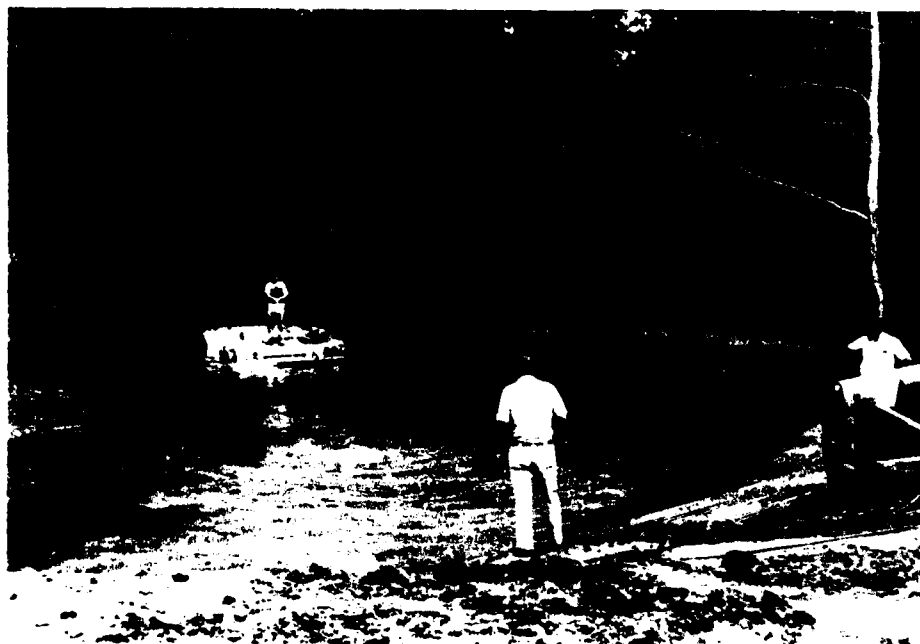


b. Mat sections inverted being pulled unsuccessfully into lake by the M113 APC

Photo H8. M8A1 (upside-down) mat-covered slope tests,
Brown Lake area (Sheet 1 of 4)

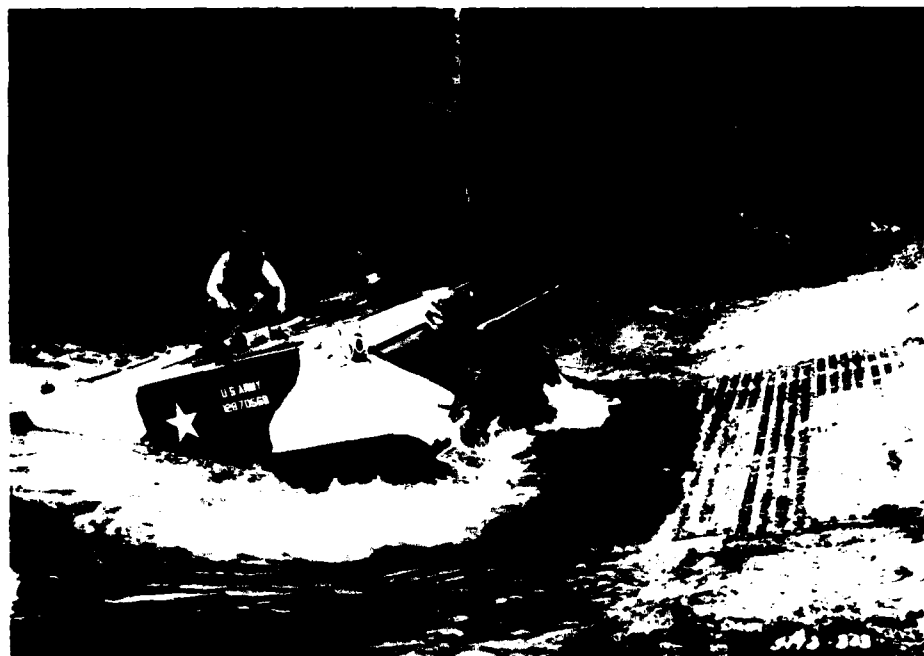


c. D-6 bulldozer being used to push mat sections
downslope into lake



d. Sandbag anchors being placed in lake (note one
entangled line being freed by WES personnel)

Photo H8. (Sheet 2 of 4)



e. M113 APC starting upslope on inverted mat



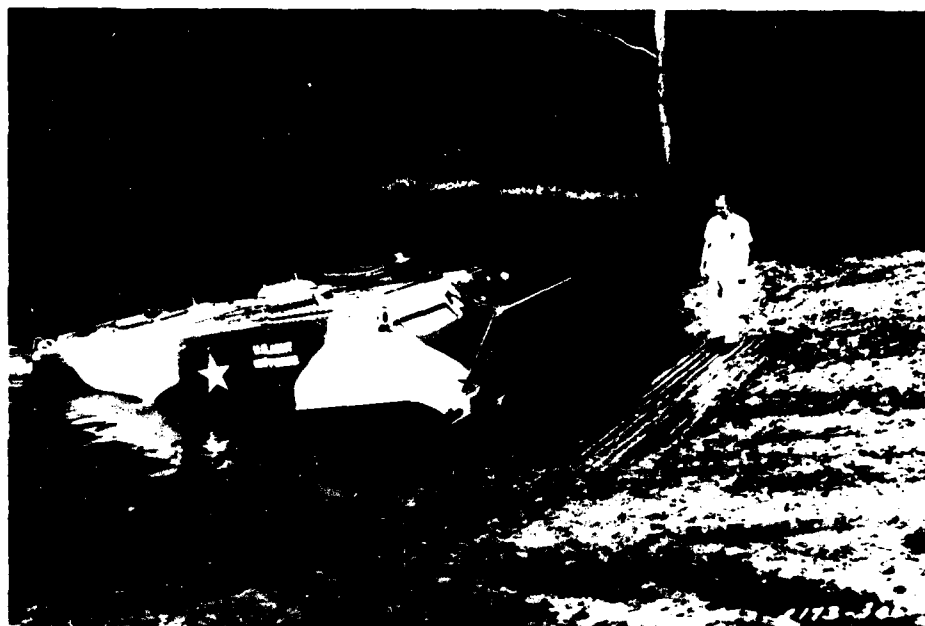
f. M113 APC almost successfully exiting lake (note mat was pulled downslope until "go" condition encountered with mat located as shown in Photo H5g)

Photo H8. (Sheet 3 of 4)



g. Mat anchored at point on slope/lake edge where "go"
upslope with the M113 APC was accomplished

Photo H8. (Sheet 4 of 4)

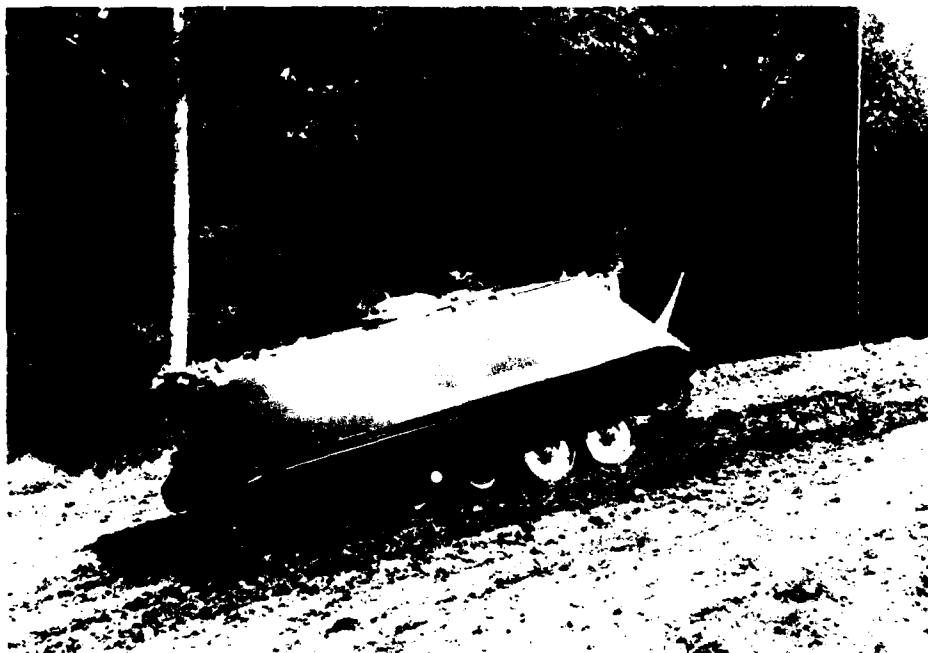


a. M113 APC easing from lake onto mat at slope/water interface



b. M113 APC successfully negotiating mat/slope interface and climbing slope

Photo H9. M8A1 matted water/slope interface tests,
Brown Lake area (Sheet 1 of 9)



c. M113 APC near top of slope on first "go" condition

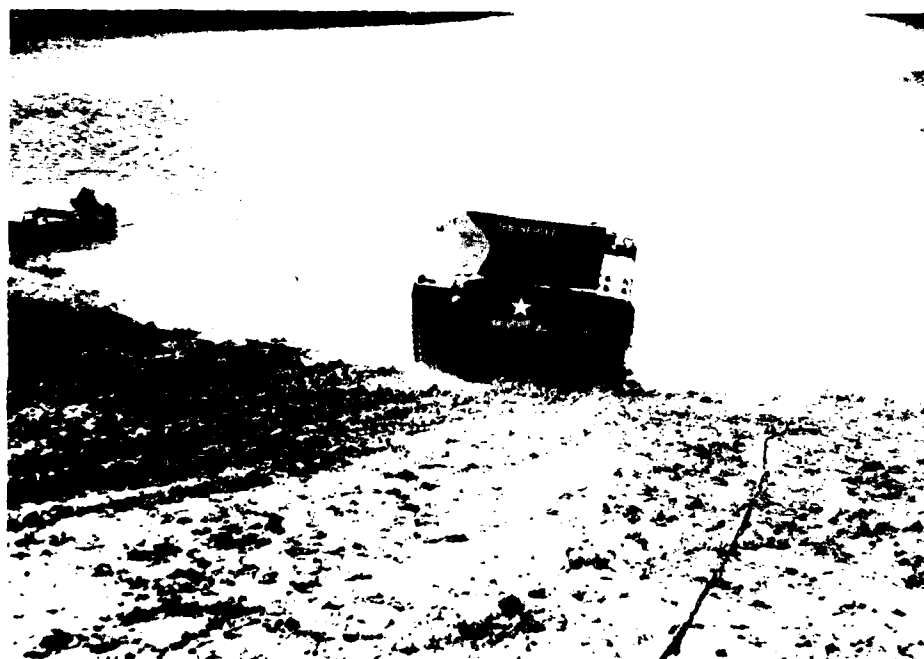


d. Mat sections and anchors pulled toward lake and skewed by tractive elements of the M113 APC

Photo H9. (Sheet 2 of 9)

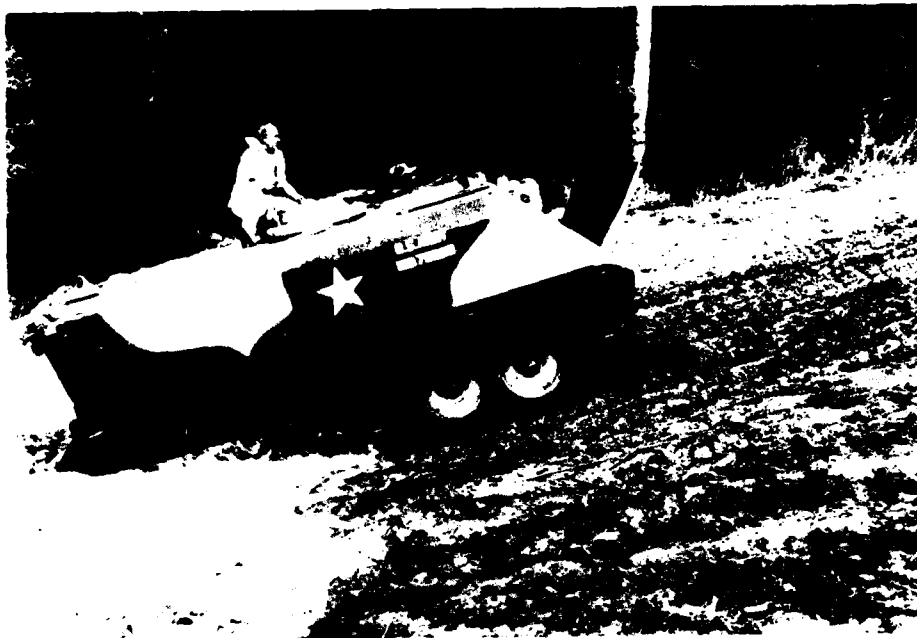


e. Reanchored mat after realignment and reanchoring



f. M113 APC spinning on mat at water's edge

Photo H9. (Sheet 3 of 9)

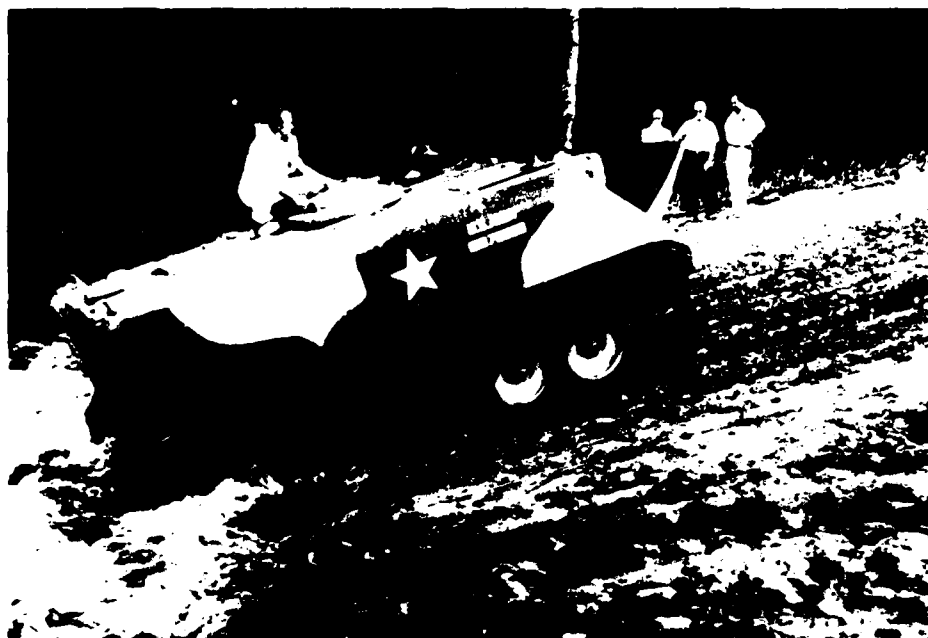


g. Vehicle negotiating mat and climbing upslope

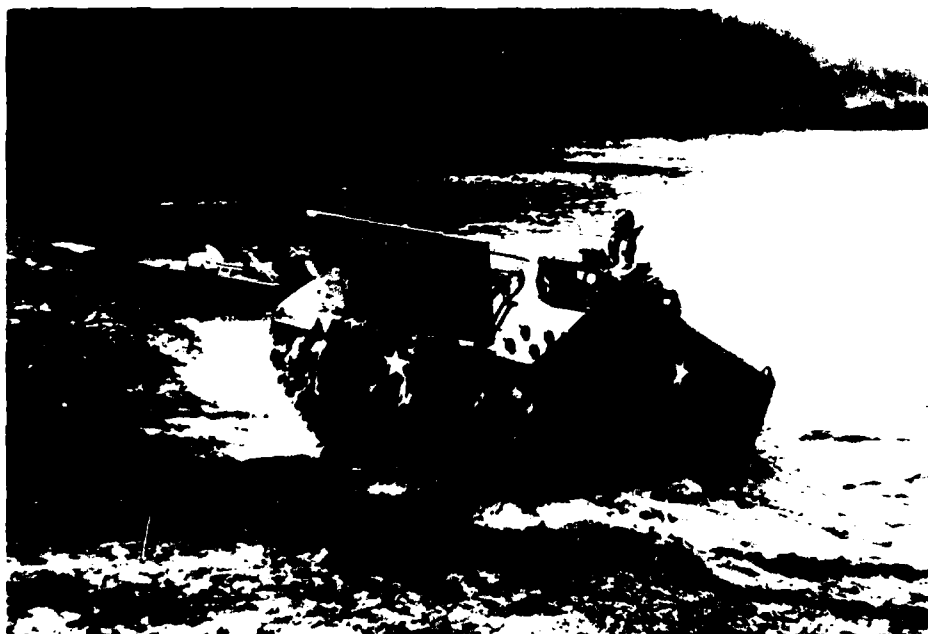


h. Third pass for vehicle with inverted mat starting at water's edge

Photo H9. (Sheet 4 of 9)

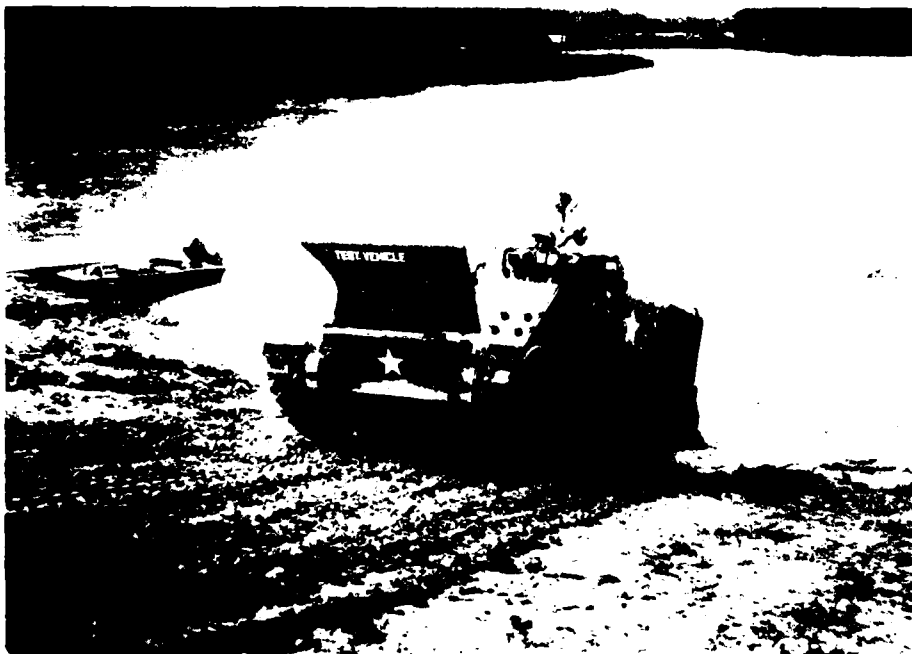


i. Fourth pass upslope with the M113 APC



j. Swimming-climbing technique developed to ensure successful negotiation of slope

Photo H9. (Sheet 5 of 9)

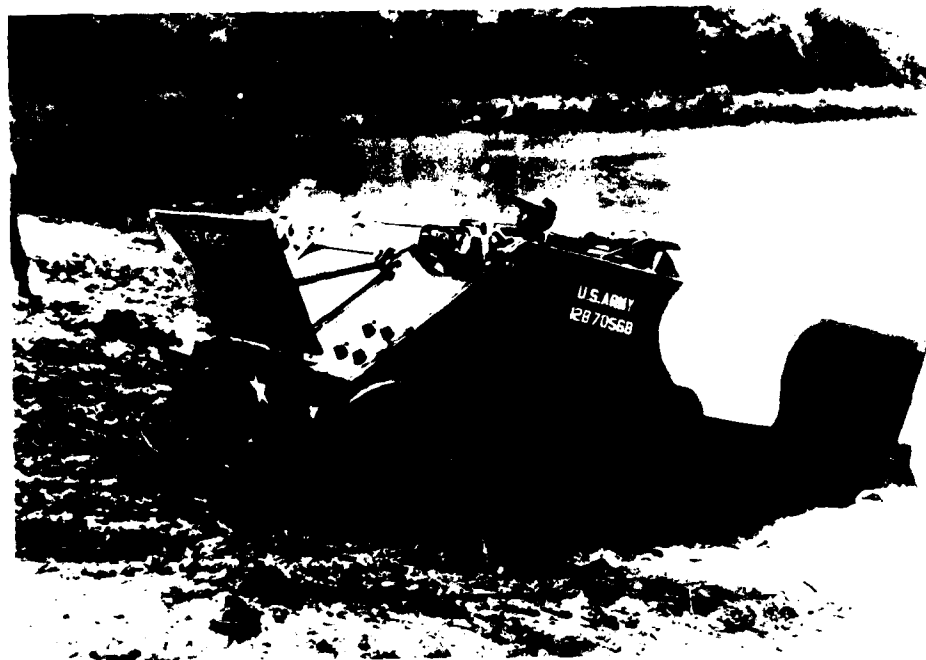


k. Vehicle completing one of last few passes before
25 completions on dry slope

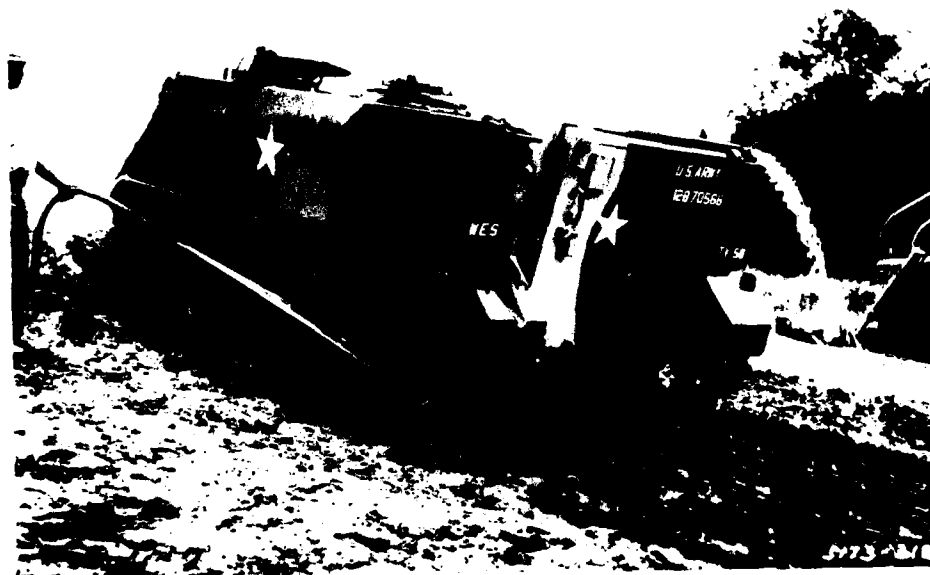


l. Toe of slope after 25 passes with no mat visible
at water's edge

Photo H9. (Sheet 6 of 9)

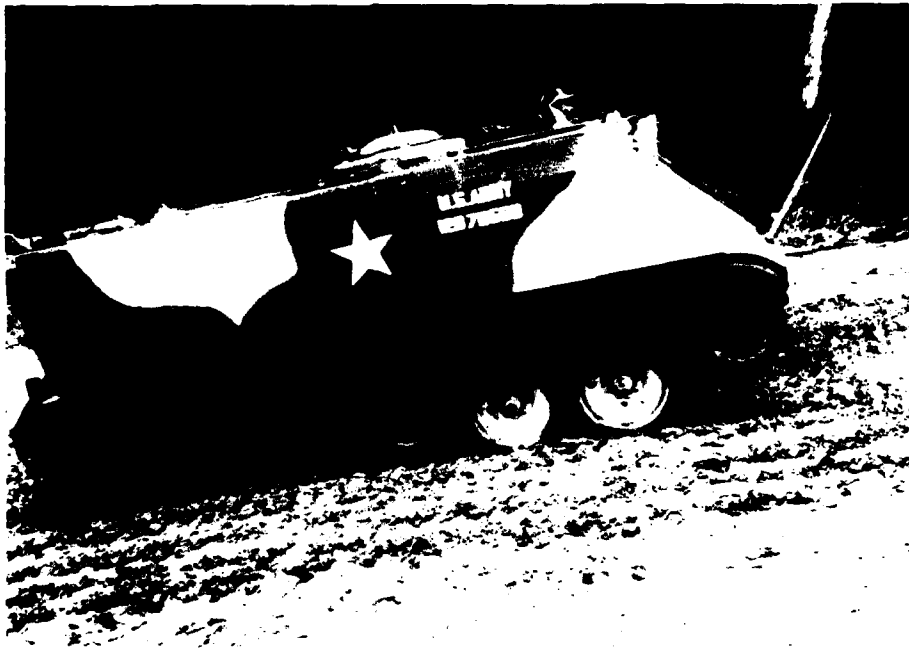


m. First pass with slope being sprayed with water from spray truck



n. Vehicle near top of slope showing water spray from nozzle and bilge

Photo H9. (Sheet 7 of 9)



o. Vehicle completing last pass on mat with wetted slope

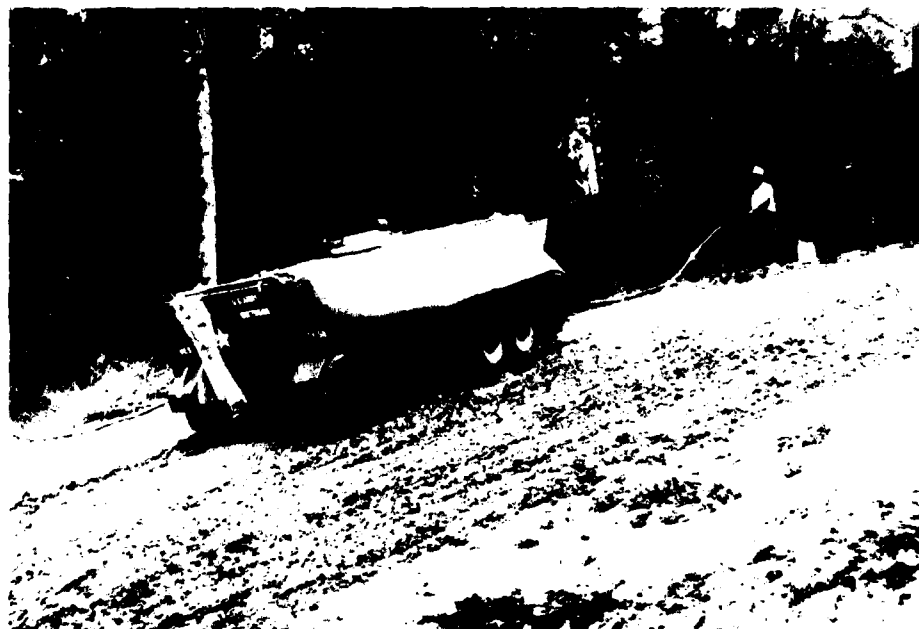


p. Slope/water interface after completion of test series

Photo H9. (Sheet 8 of 9)



q. Upper slope after completion of test series



r. View of vehicle traveling upslope on wet surface
with little or no slippage

Photo H9. (Sheet 9 of 9)

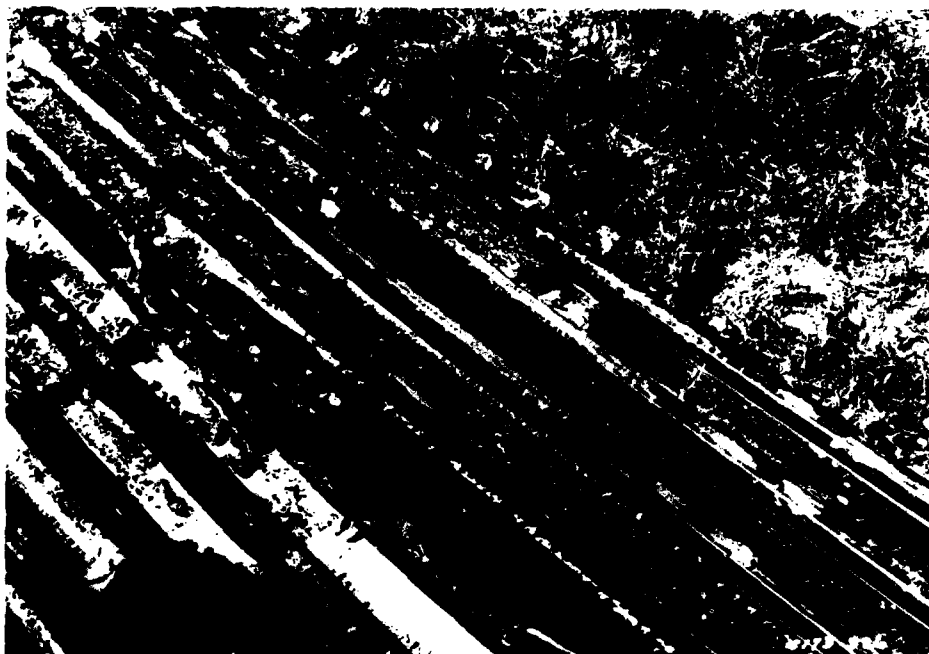


a. View of mat, inverted, rolled edge toward lake, after tests



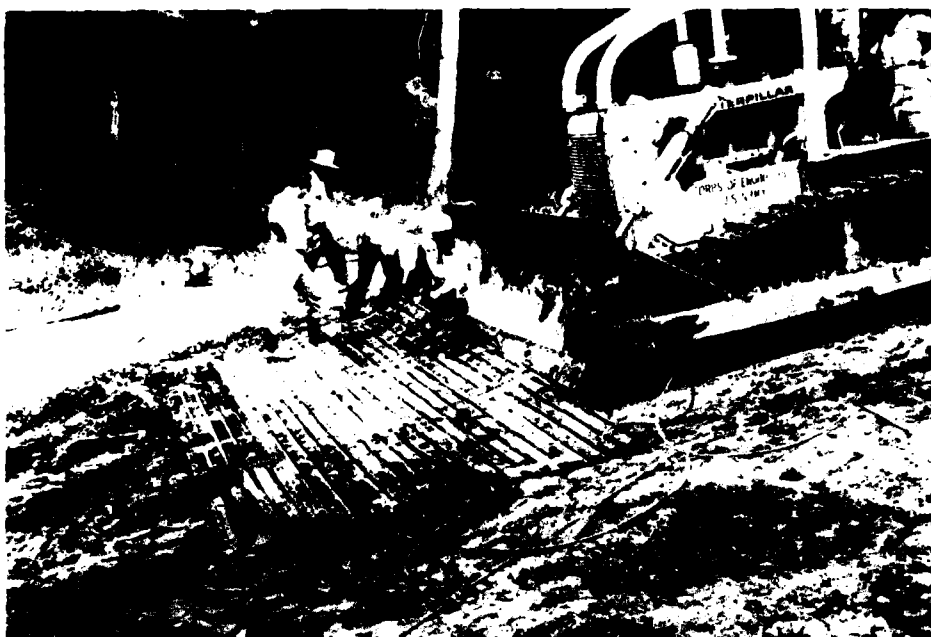
b. Close-up of mat ridges showing damage from track slippage

Photo H10. Damaged M8A1 after vehicle tests
Brown Lake area (Sheet 1 of 2)



c. View showing rolled edge of mat opened by
tracks of the M113 APC

Photo H10. (Sheet 2 of 2)

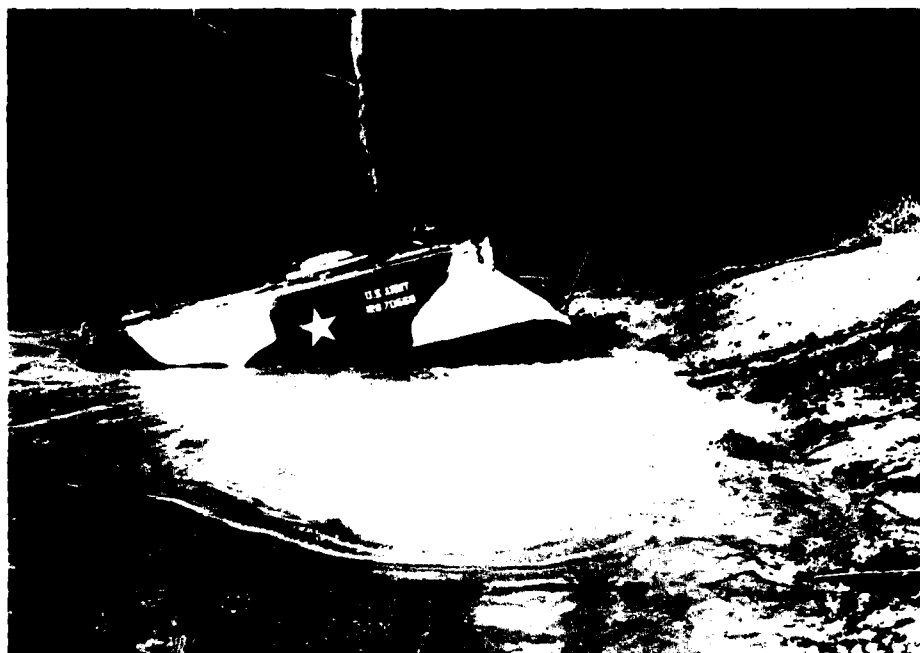


a. Mat right side up with rolled edge downslope being pushed into water by the D-6 bulldozer

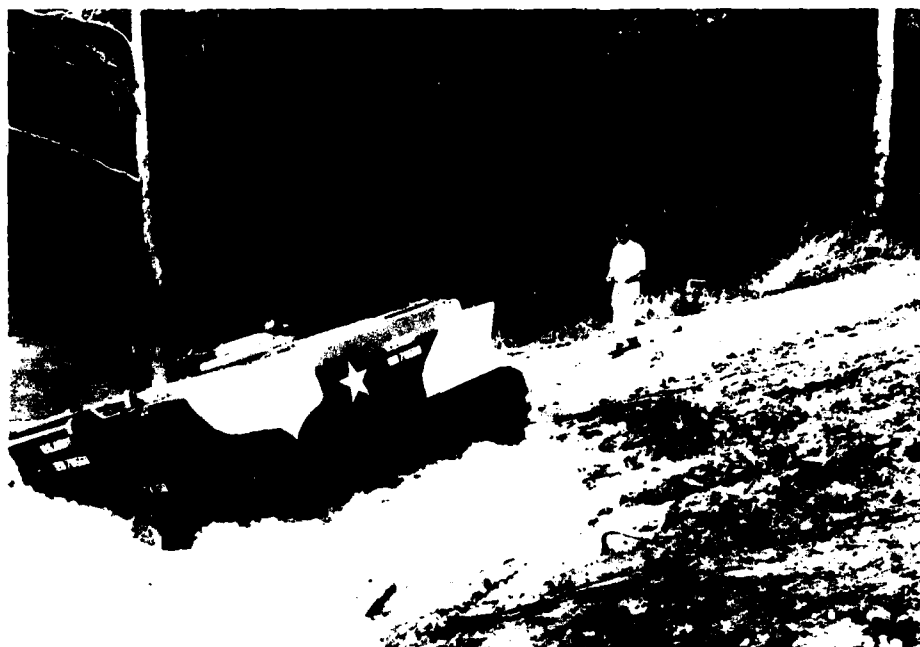


b. M113 APC encountering mat in lake near water's edge

Photo H11. M8A1 matted slopes, underwater, Brown Lake area (Sheet 1 of 9)

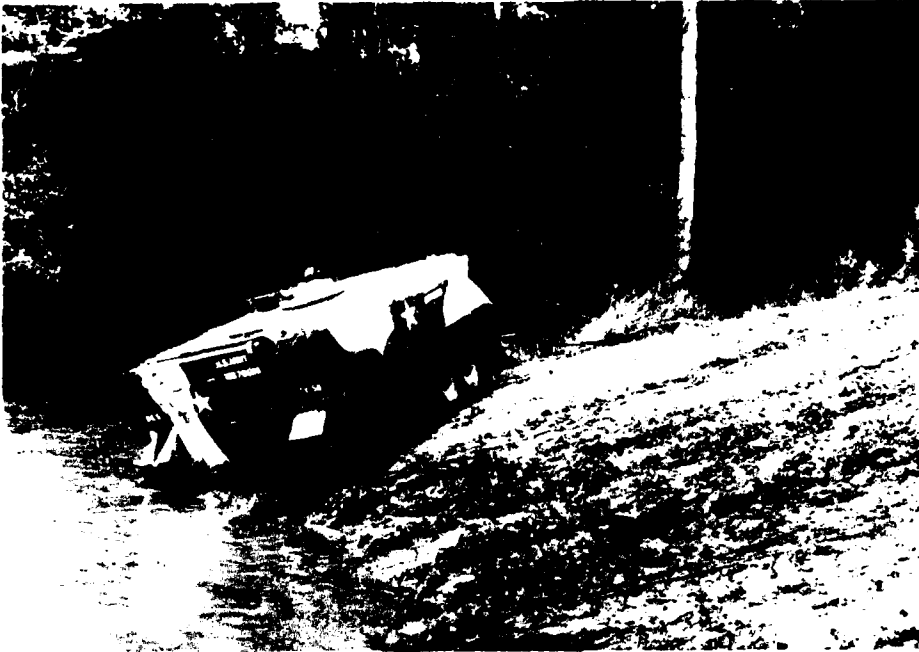


c. M113 APC attempting unsuccessfully to climb unsurfaced slope

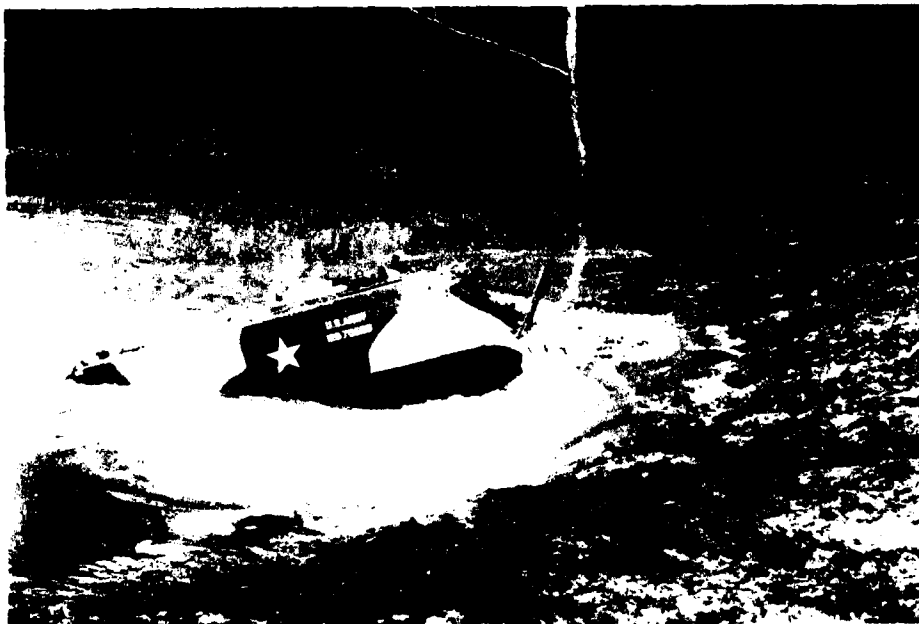


d. M113 APC slipping sideways on mat underwater

Photo H11. (Sheet 2 of 9)

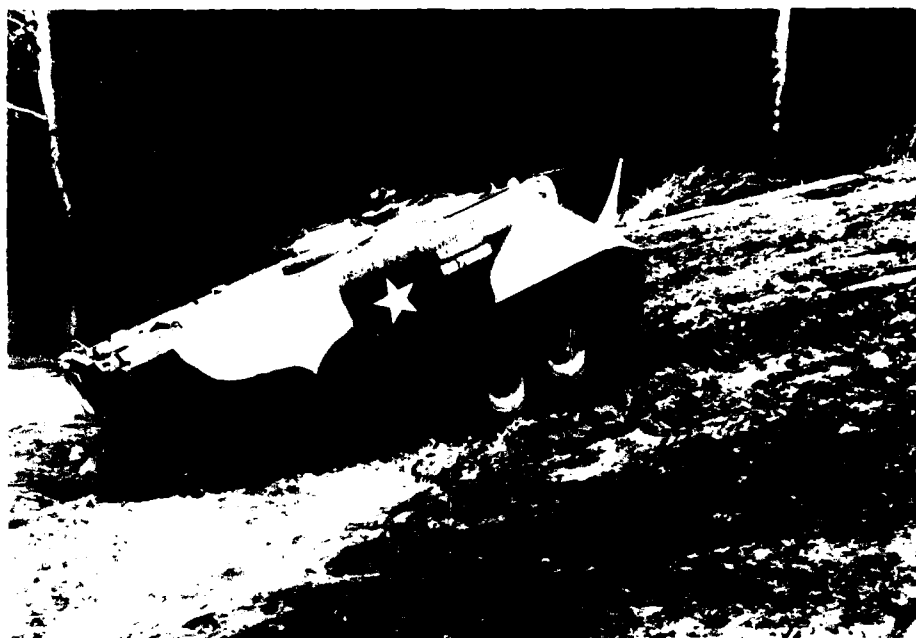


e. M113 APC exiting lake at an angle after edging off end of mat and climbing slope



f. M113 APC encountering mat, which has been flipped from last test (Photo H8e) and placed in lake inverted, hooked edge into lake

Photo H11. (Sheet 3 of 9)

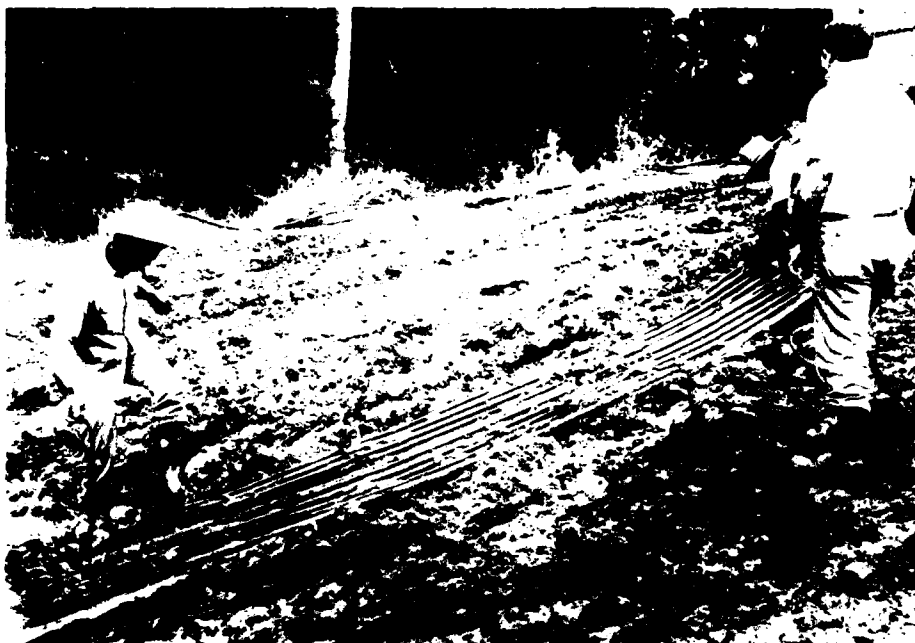


g. Vehicle spinning slightly, then climbing over mat onto slope



h. Vehicle climbing toward rest of wet slope

Photo H11. (Sheet 4 of 9)



i. View of mat being removed from lake showing distortion of panels with vehicle traffic



j. Two runs of mat, inverted with rolled edge downslope, being pushed into lake for egress test

Photo H11. (Sheet 5 of 9)



k. Views of "unrolled" edge of mat



l. General view of test area

Photo H11. (Sheet 6 of 9)



m. View of vehicle test after mat replaced on slope
right side up, rolled edge down



n. Another unsuccessful vehicle test on right-side-up mat

Photo H11. (Sheet 7 of 9)

AD-A139 480

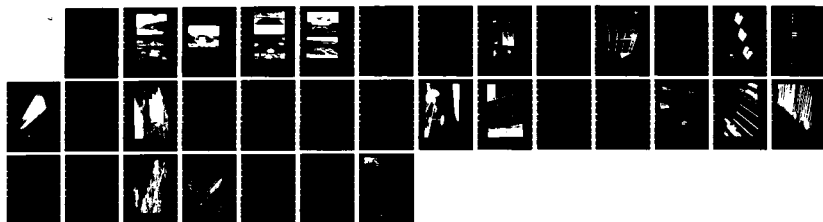
TACTICAL BRIDGE ACCESS//GRESS PRELIMINARY
INVESTIGATIONS(U) ARMY ENGINEER WATERWAYS EXPERIMENT
STATION VICKSBURG MS GEOTECHNICAL LAB B A MATIS SEP 80

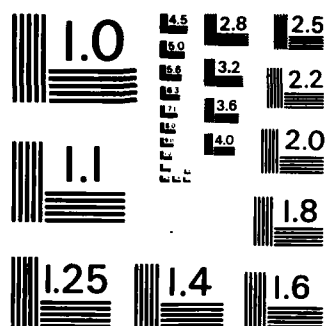
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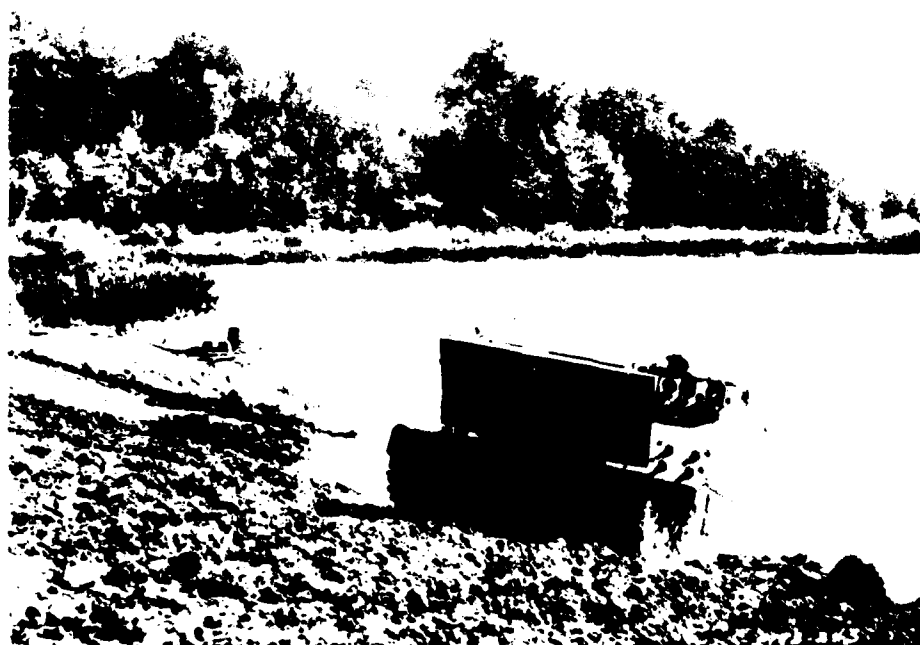




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



o. Vehicle sliding sideways on right-side-up mat



p. Frontal view of vehicle spinning on mat, underwater,
right side up

Photo H11. (Sheet 8 of 9)

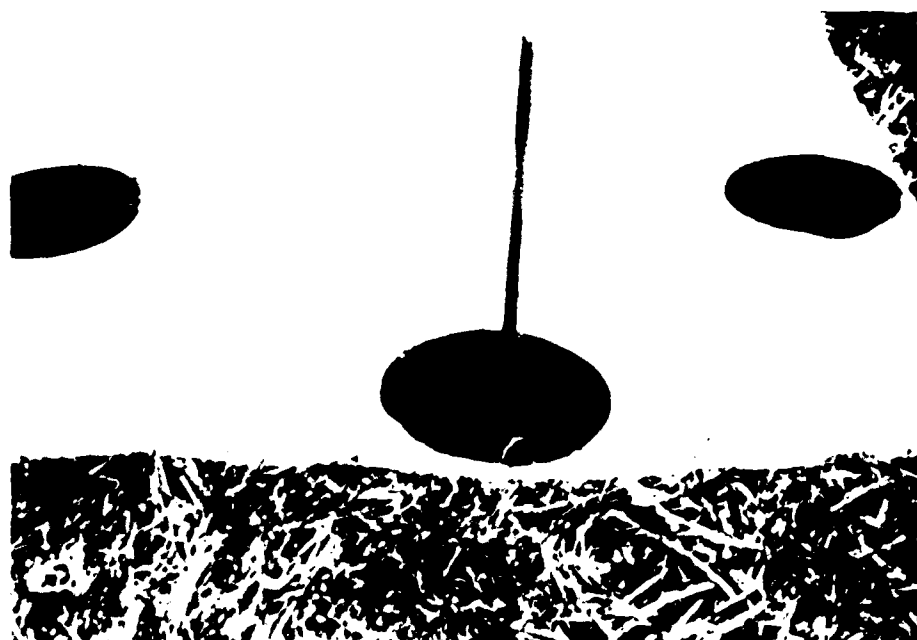


q. Frontal view of vehicle spinning on mat at water's edge

Photo H11. (Sheet 9 of 9)

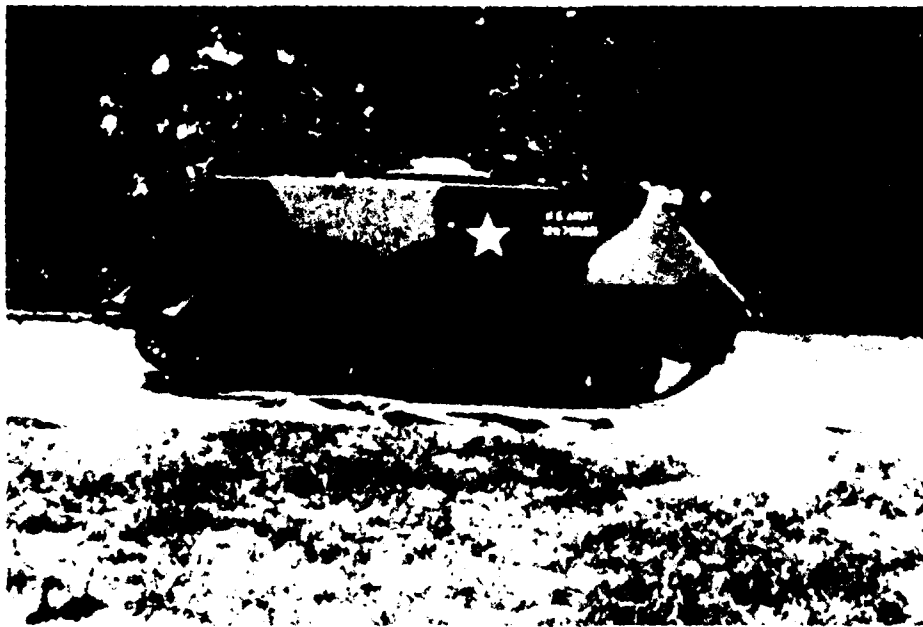


a. View of stretched and tacked T17 membrane on level surface

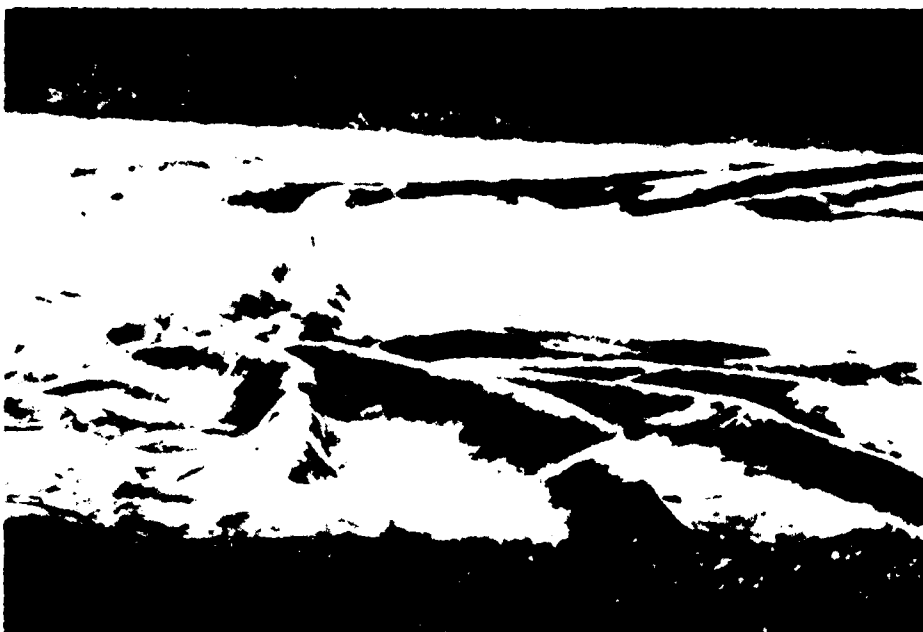


b. View of tack anchors used to secure membrane to soil

Photo H12. Drawbar pull tests on level grass area,
WES (Sheet 1 of 2)



c. Drawbar pull test on T17 membrane showing membrane stretching beneath tracks



d. Close-up of stretched T17 membrane from beneath tracking the M113 APC

Photo H12. (Sheet 2 of 2)

APPENDIX I

INSTALLATION AND SERVICEABILITY OF INVENTORY ITEMS,
T17 MEMBRANE AND M19 AND M8A1 LANDING MATS, FOR
INTERIM USE AS BRIDGE ACCESS/EGRESS
SURFACING MATERIALS*

* The LOA mentioned in this appendix refers to the LOA that comprises Appendix A of this report.

Introduction

1. The need for surfacing over marginal soil materials to expedite Army traffic to and from hastily constructed structures has long been recognized. How and where the Army goes in time of combat is often dependent upon its ability to negotiate stream crossings. The Army's experience and lessons learned are well documented, studied, and used as a guide to develop more rapid methods or systems of crossing streams. As these developments are under way, their requirements are constantly changing in regard to material weight, cost, placement time, manpower, etc. Before undertaking the bridge access/egress research project, it was considered prudent to determine to what degree, if any, Department of Defense current inventory items, such as aircraft landing mats and prefabricated membrane, would meet these requirements.

2. Headquarters, U. S. Army Materiel Development and Readiness Command, funded the bridge access/egress project. The manager of the project, the U. S. Army Mobility Equipment Research and Development Command (MERADCOM), and the U. S. Army Engineer Waterways Experiment Station (WES) developed a Letter of Agreement (LOA) for the WES to perform the research and engineering tests on materials to meet the stated LOA requirements and to determine to what extent present expedient surfacing inventory items meet these requirements. A copy of the LOA, dated 24 July 1979, is presented in Appendix A.

Description of Inventory Materials and Ancillary Items

M19 airplane landing mat
(Federal Stock No. 5680-089-5920)

3. Panels. The M19 mat is a sandwich-type structure containing a 1.375-in.-thick aluminum honeycomb core bonded top and bottom to 0.063-in.-thick aluminum skins as shown in Figure 11. Extruded aluminum connectors are bonded to the edge of the core with a potting compound and welded to the top and bottom skins. Two edges of the panel have overlap-and-underlap-type joints that are connected to adjoining panels and locked with an extruded aluminum locking bar. The other two edges

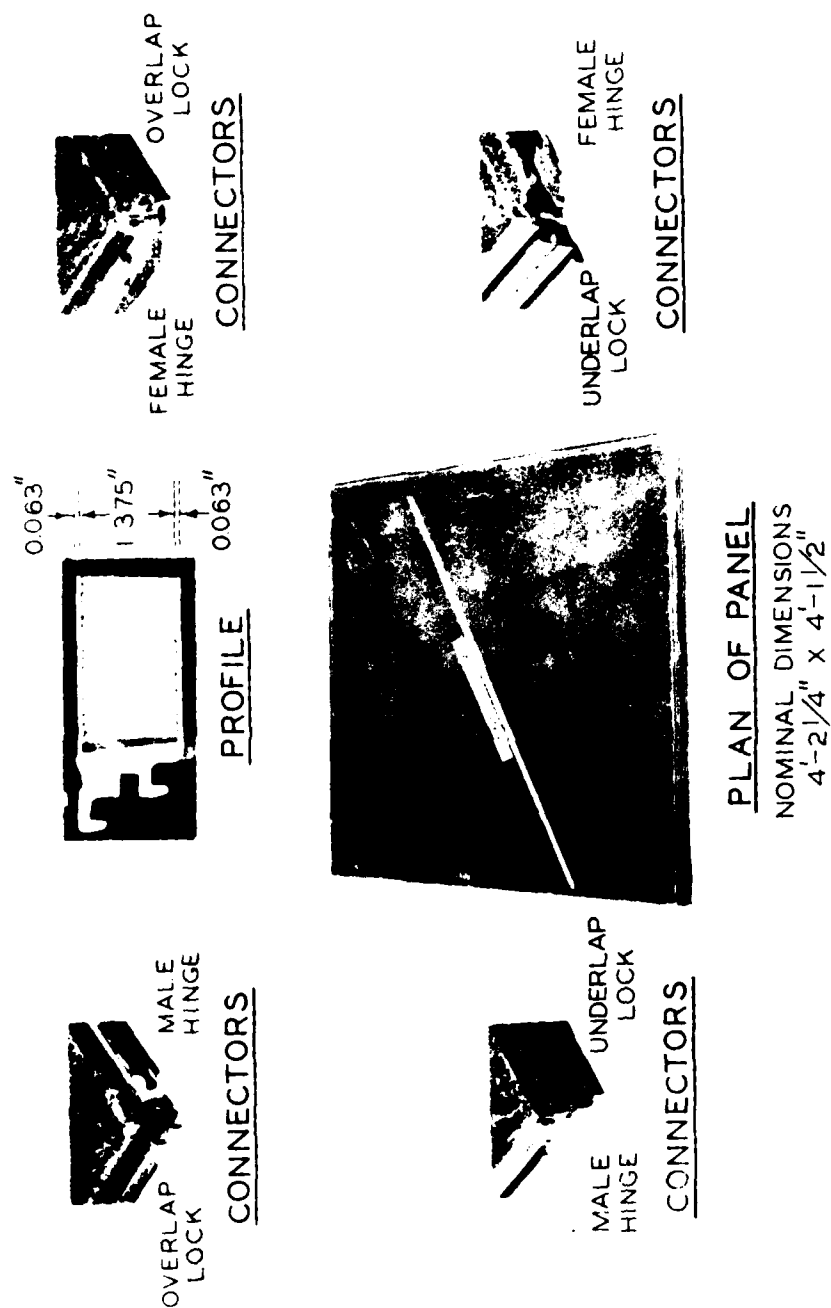


Figure I1. Composite of the M19 aluminum landing mat

have male- and female-type connectors. The individual panels, 1.5 in. thick, 50-1/4 in. long, and 49-1/2 in. wide, weigh approximately 71 lb. A panel covers approximately 16.7 sq ft and weighs 4.3 lb per sq ft of placing area. The panels can be placed at a rate of 573 sq ft per man-hour. A basic mat placing crew consisting of seven men (one NCO and six EM's) is required for placement on a 20-ft-wide front (road width). The panels are normally laid with the male-female joints parallel to the direction of traffic and continuous along the road length (Green and Ellison, 1969).* The traffic is, therefore, always applied in a direction perpendicular to overlap-underlap connector locking bars.

4. Pallets. Mats and necessary ancillary items are packaged in crates for shipment to the theater of operations (TO). The crates are skid mounted for ease of handling with mechanized equipment. The various pallets are described below.

5. Full-mat pallets (FSN 5680-930-1524) are stacked on four-way entry wood skids to make a pallet package of 32 mats (Headquarters, Dept. of the Army, 1968). Each mat is supplied with one locking bar placed in the upward facing groove of the underlap edge of the mat plus one additional bar per bundle, making a total of 33 bars per bundle. All sides of the pallet are covered with sheets of plywood, and the corners are protected by angular aluminum strips. The package is bound with steel bands (Figure I2). Gross weight is 2484 lb, and bundle dimensions are 51-3/4 in. long by 51 in. wide by 55 in. high, or 84 cu ft per bundle.

6. Half-mat pallets (FSN 5680-930-1525), specially marked, are similar to the full-mat pallets, except they are approximately half the size of the standard mat bundles (Headquarters, Dept. of the Army, 1968). The half panels are bundled in pallets containing 32 half panels and 33 locking bars. In the normal placement pattern, half panels would be required at the ends of the complex to maintain a straight edge. In some placement patterns, the male-female joint is continuous across the roadway width (perpendicular to traffic directions), and half panels are

* References cited in this appendix refer to REFERENCES at the end of the main text.

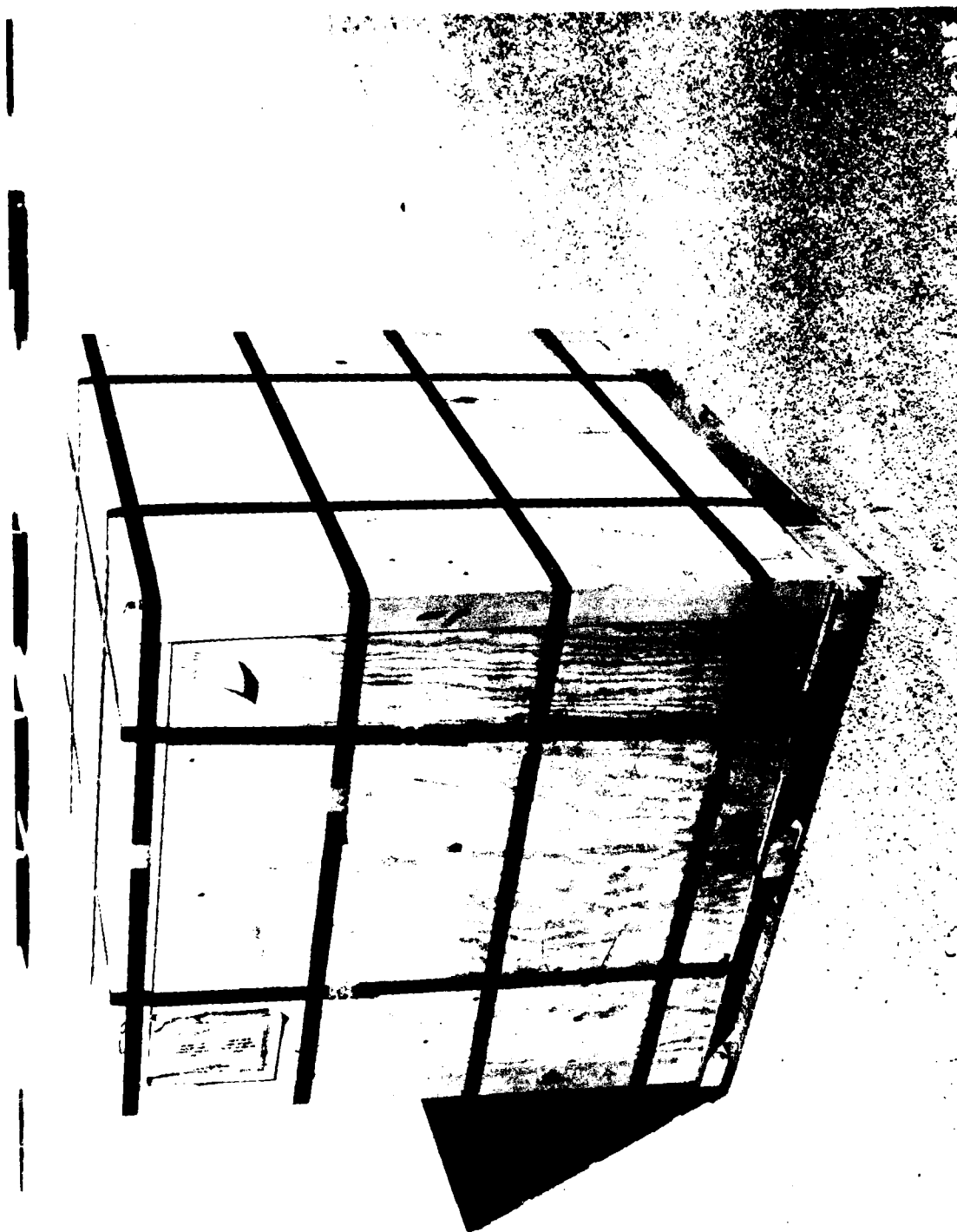


Figure 12. Bundle of 32 full panels

not required. However, to maintain the brick-laying pattern, the edges of the roadway would be irregular or jagged.

7. Additional pallets, male-female anchor attachments, and earth anchors (Figure I3) are crated in packages of 125, 175, and 250, respectively.

M8A1 airplane landing mat
(Federal Stock No. 5680-781-5577)

8. Panels. The M8A1 panels are formed of 0.125-in.-thick steel sheets (Headquarters, Dept. of the Army, 1973). As shown in Figure I4, the panels are solid planks with no pierced holes. The end connections incorporate moment-transferring joints made of four 3/4- by 3/4- by 10-1/2-in. sliding steel pins that are driven into place with a hammer or bar after the panels are placed. The side connector hooks are along one side of the panel only, and the opposite edge is rolled under the hook slots to form a smooth contour at the subgrade and furnish additional strength along the side. The panels can be placed at a rate of approximately 361 sq ft per man-hour on an airfield. A basic mat placement crew consists of seven men (one NCO and six EM's) on an 18-ft-wide road.

9. Pallets. A standard pallet (bundle) consists of 13 full and 2 half panels bound together (Figure I5). The panels are nested in pairs in the pallets. The pallet is 1.88 by 12.21 by 0.91 ft, or 20.9 cu ft, and weighs 2036 lb. Before transporting the bundles to the site for placement, the bundles should be opened, rearranged with panels added, and rebundled. The new bundle will consist of 10 full and 10 half panels (the equivalent of 15 full panels) with the individual panels oriented and stacked as they will be placed. The extra half panels are made by cutting a full panel at the transverse center line. The panels should be stacked bottom to top with the connector hook edges on one side of the bundle and the rolled edge, which contains the connector slots, on the opposite side of the bundle. A bundle will consist of five groups of panels bound together with straps. Each group is made up of panels stacked on top of each other--one full, two halves, and one

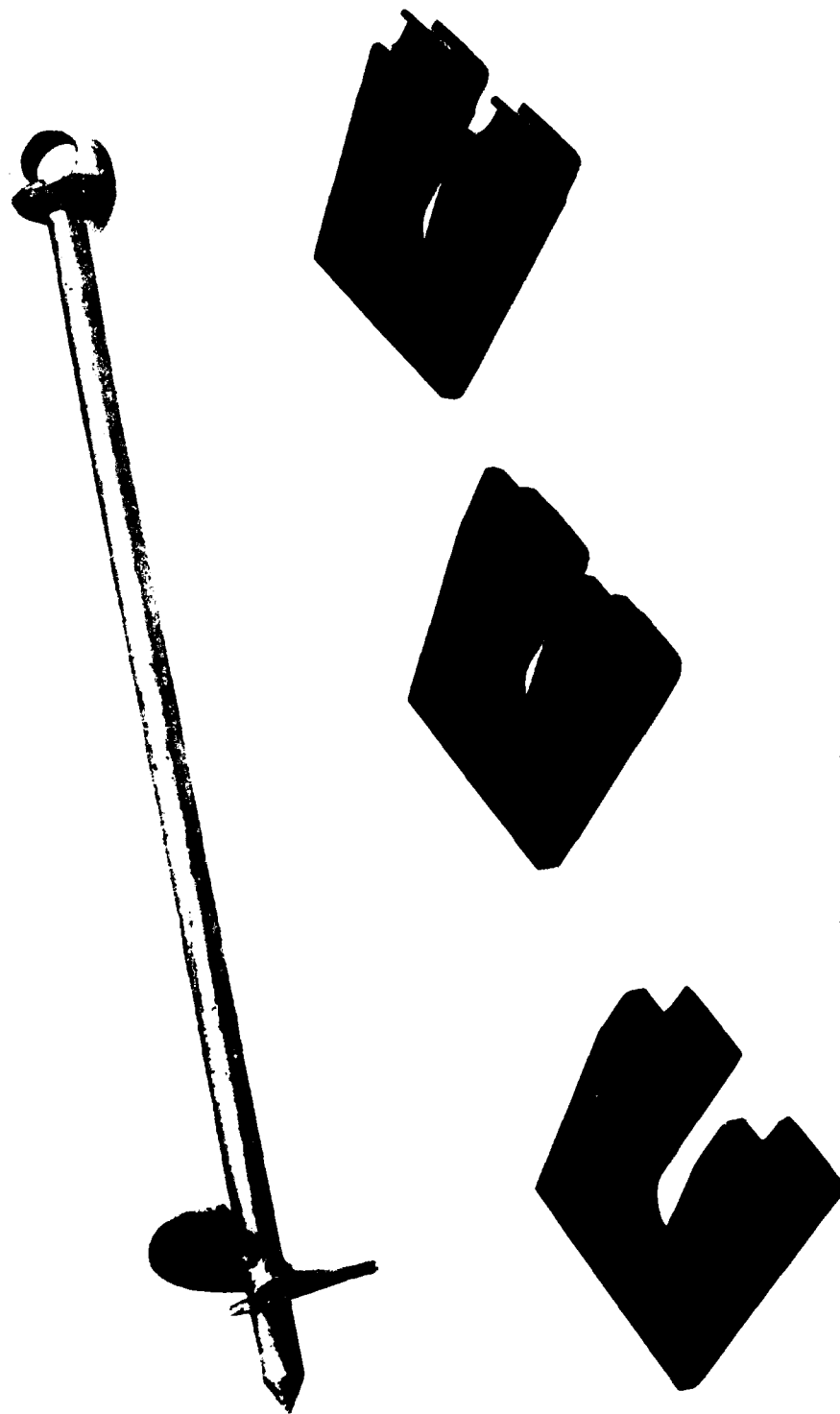
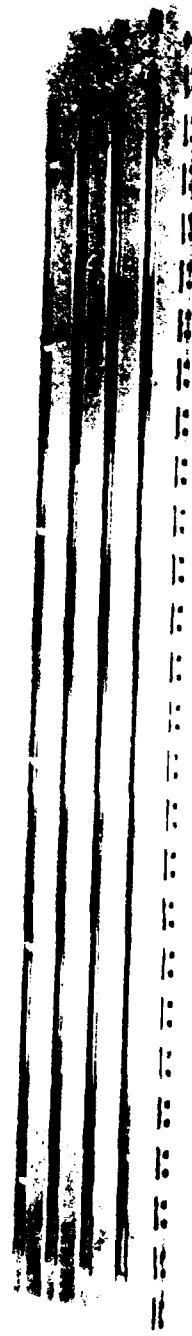


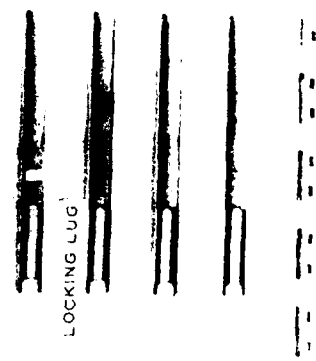
Figure I3. Earth anchor and attachments



PLAN VIEW OF PANEL
NOMINAL DIMENSIONS
1'-7" x 11'-9"



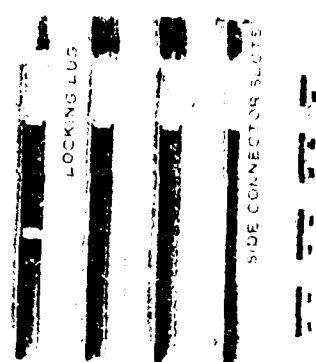
VIEW OF LEFT END



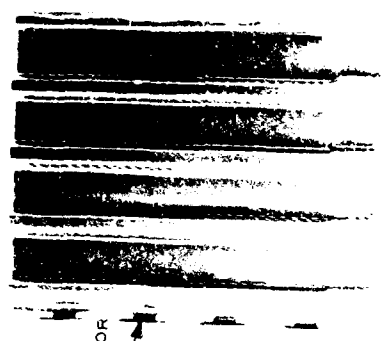
DETAILS LEFT END



VIEW OF RIGHT END



DETAILS RIGHT END



BOTTOM VIEW RIGHT END

SIDE CONNECTOR
HOOKS

Figure 14. Composite of the M8A1 steel landing mat

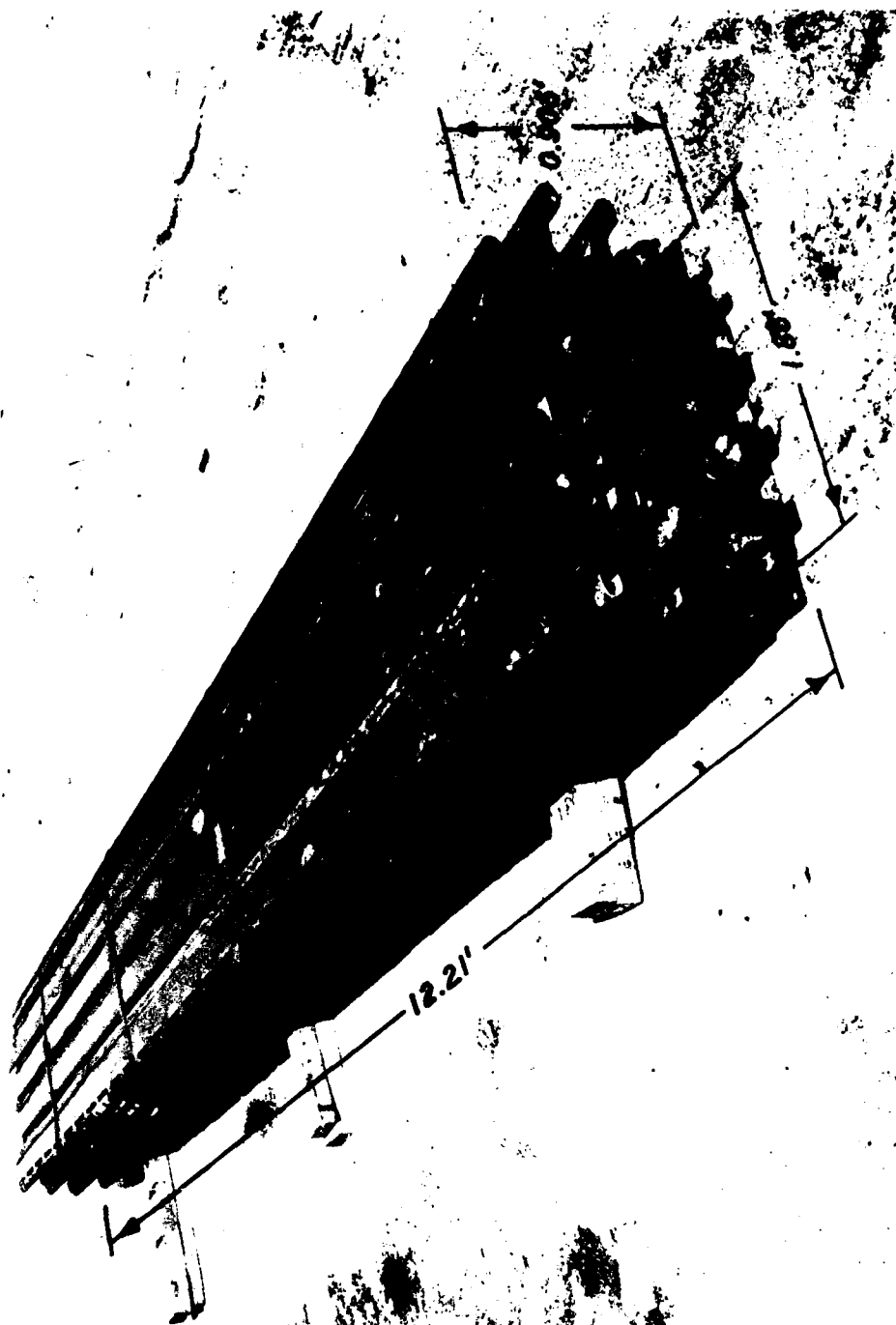


Figure I5. Bundle of 13 full and 2 half panels

full. The rebundle will be 1.7 by 12.1 by 1.4 ft, or 28.8 cu ft, and will weigh approximately 2180 lb.

T17 membrane (Federal
Stock No. 5680-00-93CL-E1)

10. The T17 membrane is a neoprene-coated, 2-ply nylon fabric designed to provide a dustproof and waterproof wearing surface for soil subgrades used as airfields or roadways (Headquarters, Dept. of the Army, 1966b). The surfacing consists of 54-in.-wide runs of the fabric joined with a series of 2-1/2- to 3-in.-wide adhesive, single-lap joints. An uncrated bundle (FSN 5680-00-921-8731) (Headquarters, Dept. of Army, 1973), 100 by 36 ft, ready for deployment, is shown in Figure 16. The membrane is packaged in various sizes to meet runway, helipad, taxiway, and parking area requirements. The size of the membrane surfacing can be varied by cutting to fit a particular area. A convenient size for a roadway is 100 by 18 ft. The membrane should be cut so that the direction of traffic is parallel to the adhesive seam joints. The long dimension is folded in 4-ft laps, and then the short dimension is folded back on itself from each edge to make a 4- by 4- by 1.5-ft, or 24-cu-ft, bundle weighing approximately 574 lb. The weight of the membrane is 0.33 lb/sq ft. In use, the membrane does not act as a load-distributing medium, and the subgrade must be of such strength to support any wheel load applied to the surfacing. The material acts to prevent dust and to shed water preserving the subgrade strength.

LOA Requirements, Material Installation and Service

General

11. These instructions are provided for the commander, who in the TO finds that the M19 mat, M8A1 mat, and/or the T17 membrane are the only surfacing materials available to support his vehicular traffic when there is a need for a gap crossing in a military operation such as access/egress at a stream crossing. The major LOA requirements are listed below, and each inventory item or combination of items is discussed completely as it meets these requirements.



Figure I6. Uncrated bundle of the T17 membrane, 100 by 36 ft, ready for deployment

- a. Assault vehicle egress role. The system must allow swimming and fording combat vehicles to exit streams that have slopes within their normal climbing capabilities (maximum 25 percent). The egress points must be capable of withstanding at least 25 passes by vehicles up to and including Military Load Class (MLC) 60. The system will enable one squad of an Engineer Combat Company, using current organic equipment, to simultaneously install two egress points 5 m wide and 15 to 20 m long within 15 min after arriving at the exit bank.
- b. Bridge equipment access role. The system must provide access lanes for use by gap-crossing equipment to reach bridge launch sites. The access lanes must be capable of withstanding at least 50 passes by vehicles up to and including MLC 25. The system will enable 10 people from the Engineer Assault Float Bridge Company (Ribbon), using current organic equipment, to install single lanes, 4 m wide, at the rate of 100 to 125 m in 30 min.
- c. Bridge traffic access/egress role. The system must provide roadways capable of withstanding 2000 to 3000 vehicle passes (10 percent rated at MLC 60). The system will enable one platoon of the Engineer Combat Company (Corps), using current organic equipment, to install single, 4-m lanes at the rate of 250 to 300 m in 45 min.

M19

12. When the roadway area to be covered with the M19 mat is identified and the matting and required ancillaries are onsite, the placement of panels (Headquarters, Dept. of the Army, 1965 and 1966a; Depts. of the Army and the Air Force, 1968) is begun by the NCO in charge and a crew of enlisted men as follows. The NCO should be inside the area to be covered and approximately 15 to 30 ft from and facing the starting line (across the road width). The first full panel should be placed in the right upper corner with the male connector parallel to the center line of the road (parallel to the traffic direction (Figure I7a)); the female connector, parallel to the outside edge of the road; and the underlap connector, perpendicular to the center line of the road. The second panel is placed to engage the underlap connector of the first panel with the overlap connector of the second panel, and the panels are locked together with a connector bar. (The two panels are along the outer, upper right edge of the roadway, which is row 1). All panels in row 1 are placed in this manner. The third panel (a half panel) is the

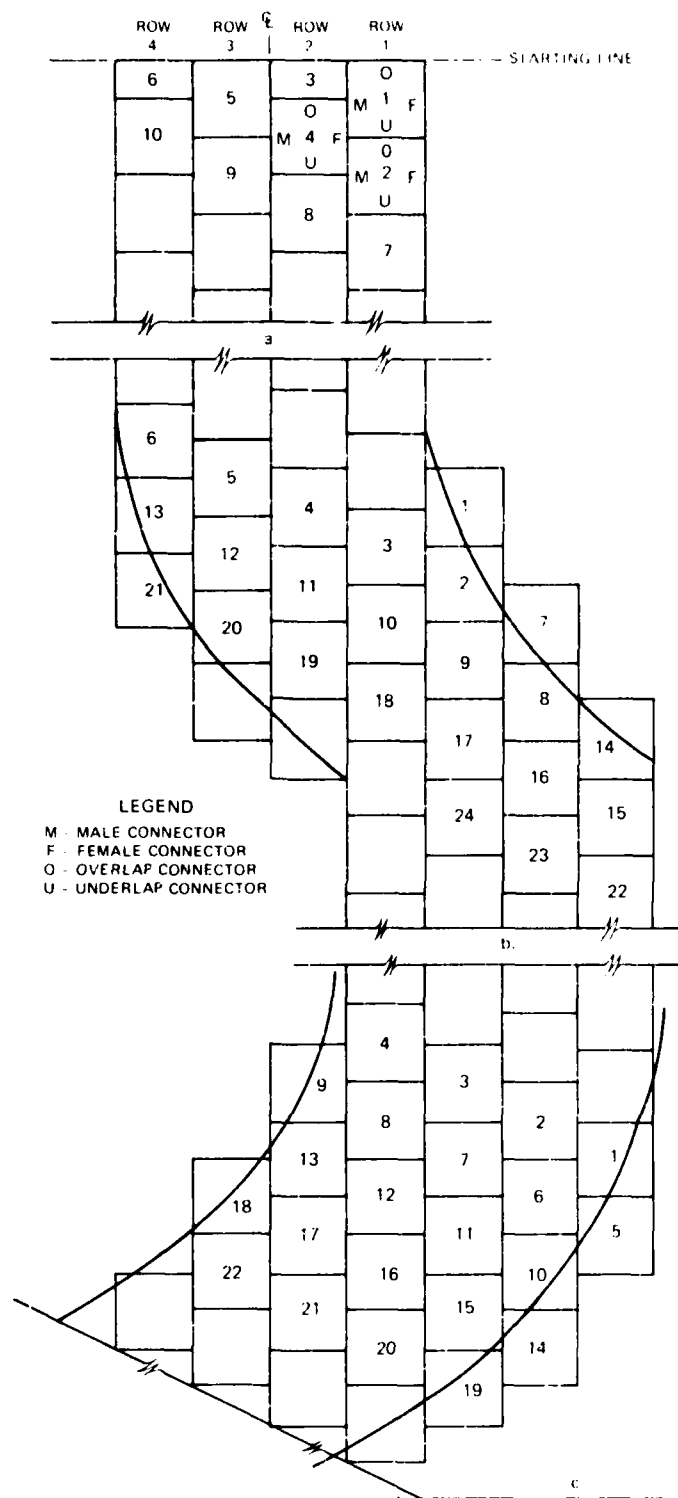


Figure 17. Placement of the M19 mat on a roadway

first panel placed in the second row and is held at 45 deg while the female connector engages the male connector of previously placed panel 1 and then hinges into position. Panel 4, connecting panels 1 and 2 along the male connector, is placed similarly to panel 3 such that panels 3 and 4 combine to form the underlap-overlap connection and are locked together by the end connector bar. Panels 5 and 6 (a half panel) are the first panels in rows 3 and 4, respectively, and are placed, as are all panels thereafter in rows 2, 3, and 4, similarly to the placement of panel 4, i.e., by holding the panels at 45 deg to the panels in place and hinging the female and male connectors together, and next dropping the panels into position so that the overlap-underlap connectors are engaged and then locked together with the end connector bar. A stair-step pattern is formed and is continued. As long as the road is straight, four rows of mats are placed with the right row (row 1) preceding row 2, etc., across the road width (Figure 17a). In this placement pattern, the mats can be placed at a rate of 573 sq ft per man-hour, using a team of two workers along each individual mat row.

13. If and when the road curves to the right of the NCO, who is in charge and facing the starting position, another row to the right of row 1 must be started and placed so that it falls into the roadway width. The panels in the new row (extreme right) are placed before the panels in adjacent rows, and the stairstep pattern is continued. Also, the first panel in any and all new rows to the right is placed by connecting the male into the previously placed female connector (keeping the staggered joints) and hinging into place (Figure 17b). This placement is opposite to the placement of panel 4 as previously described. As the road continues to curve to the right, additional rows are begun to the right to cover the roadway's width, and the pattern placement continued. This procedure is repeated as the curve continues to the right.

14. If the road swings in the opposite direction (to the NCO's left) and panels in the right row cover the outer edge of the roadway, no further panels are required in that row. To compensate for this arrangement, extra rows of panels are added to the left so that the roadway width is completely covered and the stairstep pattern of

placement is maintained (Figure I7c). The rate of mat placement on a curved surface may be slightly less than that achieved when placed on a straight roadway (see paragraph 12).

15. The M19 mat can be placed on a 25 percent hill or stream slope. This placement, which is started at the bottom and goes up the slope, is for a straight road as described in paragraph 12 (Figure I7a). An area of 651 sq ft on a 25 percent slope can be surfaced with the M19 in 24 min using six enlisted men and an NCO for a rate of 236 sq ft per man-hour, which approaches only one-fourth the rate required in the LOA for the assault egress role. The panels are anchored along the sides with three or four anchors per side in a 40-ft length. The screw anchors (Figure I3) will have to be modified as air compressors will not be available at a forward site. The anchors can be modified by cutting off the 4-in.-diam helix and using the anchor as a drive anchor. A suitable alternative for anchors is to use a 3/4- or 7/8-in.-diam reinforcing bar, 30 in. long, and bend the end 6 in. in the shape of a "7." Also, the disc anchor, made of 1/4- by 12-in.-diam steel head welded to a 3/4-in.-diam by 2-ft-long steel reinforcement bar, may be used (Figure I8). Either anchor, with the anchor attachment (Figure I3), will help to hold the panels in place. However, even when anchored, the mats will move under traffic as much as 7 in. when trafficked by 25 passes of a loaded M48A1 tank. Unanchored, the same traffic caused the mat to move as much as 20 in. As few as 75 passes of mixed traffic through mud and clay from the M113, M48A1, and M54 vehicles caused as much as 90 percent of the antiskid to be abraded from the mat in the tracking lane (Figure I9).

16. To meet the LOA bridge equipment access role, the surfacing must be capable of being placed at a rate ranging from 862 to 1076 sq ft per man-hour over a roadway width of 4 m (13.13 ft). The rate achievable with the M19 mat utilizing 10 men is 573 sq ft per man-hour or only 53 to 67 percent of that required by the LOA. The M19 mat will sustain the 50 passes of vehicular traffic up to MLC 25 as required.

17. The bridge traffic access/egress role in the LOA requires that the surfacing sustain 2000 to 3000 passes of vehicular traffic

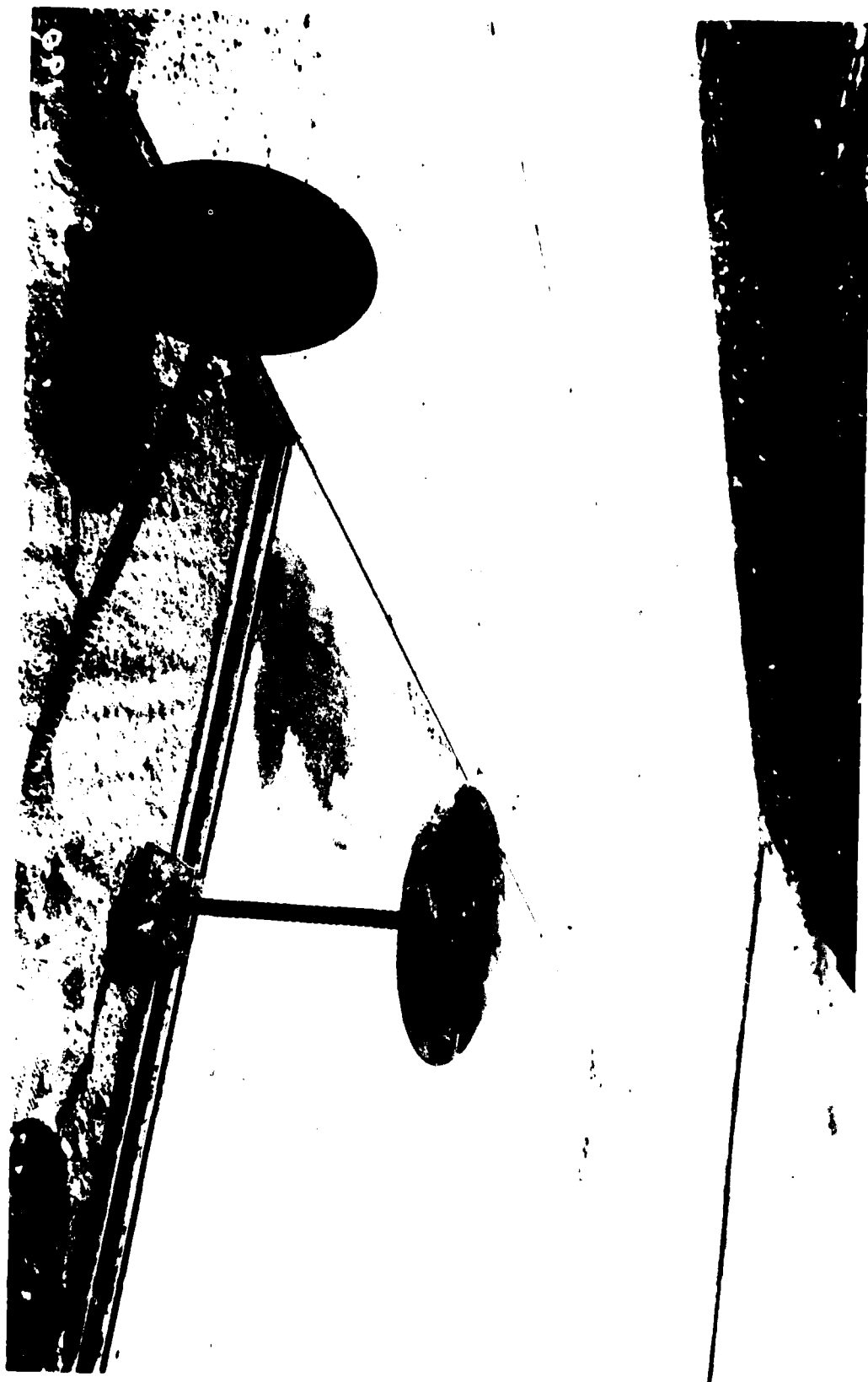


Figure I8. Disc anchors used on the M19 mat



Figure I9. Antiskid abraded from the M19 mat caused by soil and traffic

including up to 10 percent by MLC 60. Also, the surfacing is to be placed at a rate of 574 sq ft per man-hour using 30 men. As stated previously, the M19 mat can be placed at a rate of 573 sq ft per man-hour on a roadway that is 16 ft wide (four-panel widths). The panels when placed will sustain the required 3000 passes of traffic including 10 percent of which are MLC 60, without structural failure as required in the LOA for bridge traffic access/egress role.

18. The M19 mat will support all of the traffic required by the LOA on a subgrade strength of 1 to 2 CBR (California Bearing Ratio). The mats on a 25 percent slope will provide support and traction in both a wet and a dry condition for the M113 armored personnel carrier (APC), the M54 cargo truck, and the M48A1 combat tank with a gross weight of 106,000 lb. If these vehicles are trafficked through a heavy wet clay before getting on the 25 percent mat-surfaced slope, only the M113 APC can negotiate the slope for the required 25 passes; its performance is considered marginal since it becomes increasingly more difficult as more clay is tracked on the mat surface. The M48A1 tank can make only five passes in this condition, and the M54 truck cannot make any passes up the slope. However, the tank may become immobilized before five passes because of clay tracked on the mat slope.

M8A1

19. When the roadway area to be covered with the M8A1 mat is identified or selected, the placement of the mat (Headquarters, Dept. of the Army, 1965 and 1966a; Depts. of the Army and the Air Force, 1968) is begun using an NCO and six enlisted men as follows. The NCO in charge takes a position in the area 15 to 20 ft from and facing the starting line (across the road width). To cover the 4-m (13.13-ft) width, a full and a half panel (18 ft wide) in each run (one run of mat = one width of mat across the road width) are required to meet the LOA width for the bridge traffic access/egress role. On a restricted width of 18 ft, only seven men can be effectively utilized to achieve the fastest placing rate. The first side connector slot edge is inside the area (towards the NCO), and the offset end is to the right (oriented as in plan view of Figure 14). The next panel, a half panel containing end connector

bars, is placed to overlap the offset end of the first panel. The second run is started on the left edge with a half panel, which has an offset end. The half panel is held with the side connector hooks at 45 deg to the ground to engage the side connector slots. When engaged, the panel is slid approximately 1 in. to the left or right and lowered to the ground engaging the locking lug in the locking lug slot. (The sliding direction is optional on this panel only as all panels in the same run are slid the same direction and panels in alternate runs are slid in opposite directions.) The next panel in run 2, a full panel, is held and slid as the previous panel is slid to engage panels in run 1 and dropped into position. Should the roadway curve to the left, begin placing panels as far to the left to cover the curving road or simply continue adding panels to the right to extend the run as required to cover the right curving road area as the situation dictates. After 14 to 16 runs have been placed, the fastening of end connectors may be started on run 1. There should always be 14 to 16 runs between the mat placing and the fastening of end connectors so that completing the end connection does not cause misalignment of the mat. The sequence of placement is shown in Figure I10. A placing rate of 361 sq ft per man-hour using an NCO and six enlisted men can be achieved. The required 250 to 300 m (820.2 to 984.0 ft) long by 4 m (13.13 ft) wide (1,000 to 1,200 sq m or 10,770 to 12,924 sq ft), can be placed in 4.26 to 5.11 hr. This is greatly in excess of the 0.75 hr stated in the LOA for the bridge traffic access/egress role. However, the mat will sustain the 3000 passes of convoy traffic as required.

20. The M8A1 mat can be placed up a 25 percent slope. The panels are placed as described in paragraph 19, starting at the toe of the slope, except alternate runs are placed to produce a 6-in. offset (Figure I11). The offset is necessary so that drive anchors can be placed along the edges. An NCO and six enlisted men can place 662.4 sq ft in 13 min for a rate of 163 sq ft per man-hour, which is only 19 percent of the rate required in the assault vehicle egress role of the LOA. The panels are anchored along the sides (Figure I12) with three or four anchors per edge in each 40-ft length of roadway, using any suitable



Diagram 1



Diagram 2



Diagram 3

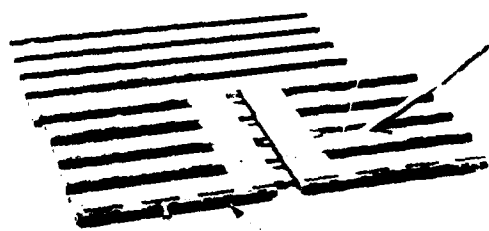


Diagram 4



Diagram 5

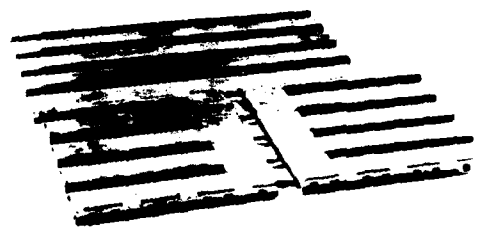


Diagram 6

Figure 10. Sequence of placing the M8A1 mat



Figure 111. Runs of the M8A1 mat offset at ends for anchoring

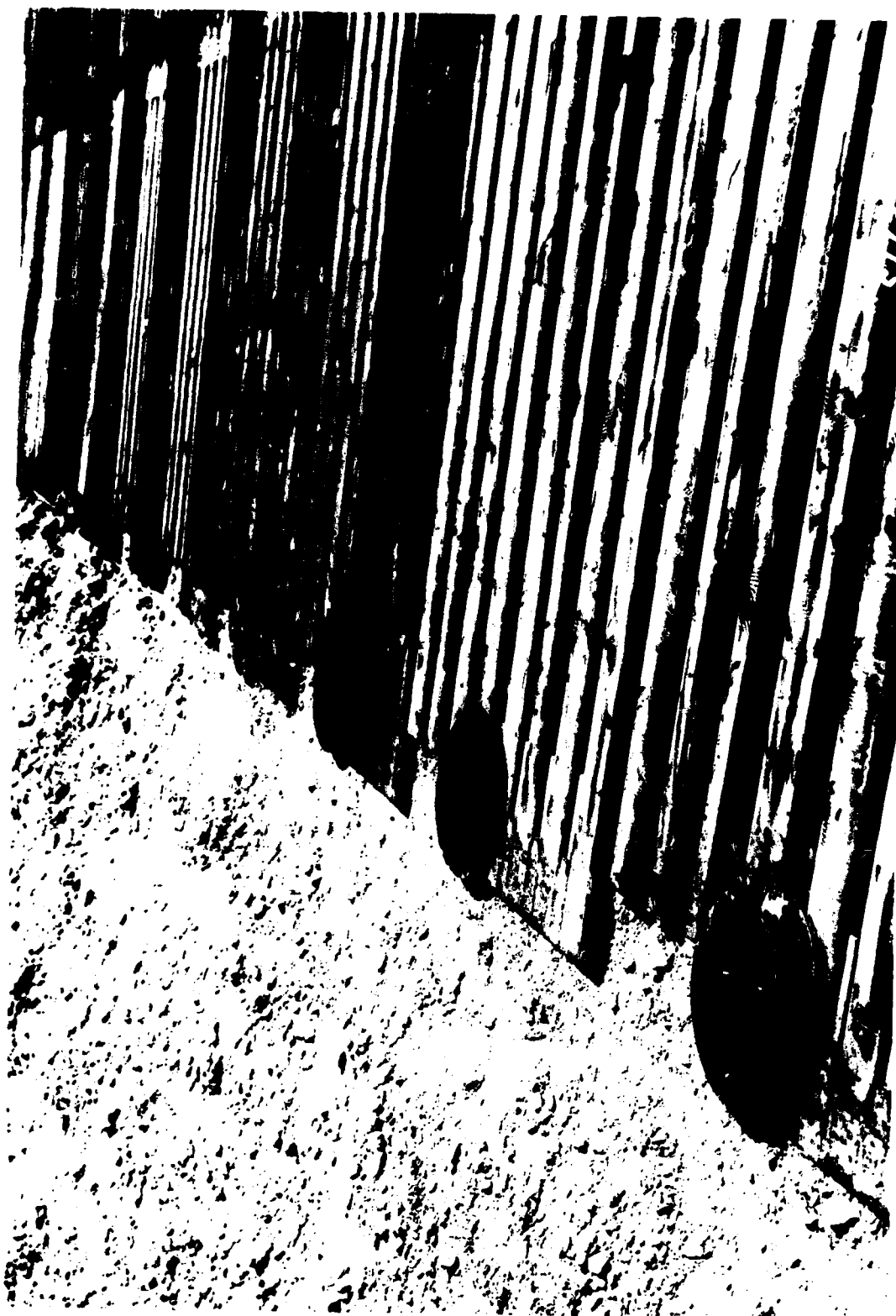


Figure I12. Disc-type anchors along the M8A1 mat

2-ft-long drive anchors as described in paragraph 15. Seventy-five passes of mixed traffic (which meet the assault egress requirement) will cause the anchored panels to move down a 25 percent slope approximately 2 in.

21. To meet the LOA bridge equipment access role, the surfacing must be capable of being placed at a rate of 1077 sq ft per man-hour over a maximum roadway width of 4 m (13.13 ft). To meet the 13.13-ft-wide dimension, one and a half panels per run will be required. A placing rate of 361 sq ft per man-hour can be achieved using seven men (discussed in paragraph 19). At this rate, it will require from 1.71 to 2.13 hr to place the required 100 to 125 m, respectively, which is greatly in excess of the LOA requirement of 0.5 hr. However, the M8A1 mat will support in excess of the required 50 passes by vehicles up to and including MLC 25 in the access role.

22. The M8A1 mat will also support all of the traffic required by the LOA on a subgrade strength of 1 to 2 CBR. The mats on a 25 percent slope will provide support and traction in both the dry and wet conditions for the M113 APC, the M51 dump truck, the M54 cargo truck, and the M48A1 combat tank with a gross weight of 106,000 lb. If these vehicles are trafficked through a heavy wet clay before getting on the 25 percent mat-surfaced slope, only the M113 APC can negotiate the slope for the required 25 passes; its performance is considered marginal since it becomes increasingly more difficult as more clay is tracked on the mat surface. The M48A1 tank can make three passes in this condition, and the M51 and M54 trucks cannot make any passes up the slope. However, the tank may become immobile before three passes, depending on how much wet soil is tracked onto the mat surface.

23. The M8A1 mat can be used for M113 armored personnel carriers to egress a stream with a 25 percent slope when wet. Two to five runs of mats, 18 ft wide (one and a half panels), are connected and locked (see paragraph 19). (The panels are connected so that the rolled edge of the mat is near the water's edge and the hook edge is up the slope.) The hooked panels (sections) are inverted (a crane can be used), and then the section is shoved into the water (rolled edge first) until the

closest edge is 3 to 5 ft from the water's edge. Before putting the section in the water, cables are attached to each edge of the section for anchorage. Three screw anchors per edge (Figures I13 and I13) are used. The cables are pulled tight between the mat section and screw anchors. The M113 APC made 25 passes from the lake and up the wet slope from the surfacing to meet the LOA traffic requirement. However, because of the need for equipment to invert the section and the additional effort required to anchor the panels, the placing rate and time were not noted for comparison purposes. After this use of the mats, they were not suitable for recovery and reuse as the tracks of the M113 APC deformed the panels, opened the rolled edge, broke the hooks, and caused the panels to disconnect (Figure I14).

T17

24. The T17 membrane alone will not meet any of the bridge access/ egress roles and is not a viable solution to the assault vehicle egress role. However, it may be used as a waterproofing medium under the surfacing material to better accomplish the bridge equipment access role and/or the bridge access/egress role. After acquiring the T17 membrane, it is cut to a desirable size, approximately 18 by 100 ft. The long dimension is accordin-folded to 4 by 18 ft. The edges are accordin-folded again to the center 4 ft to make a bundle approximately 4 by 1 ft high weighing 594 lb. When the starting line is determined, the accordin-folded membrane bundle is placed (Headquarters, Dept. of the Army, 1965 and 1966a) at the longitudinal center line of the roadway, and the edges are stretched across the width of the roadway. Two men per edge pulling in opposite directions can stretch the membrane, and then the NCO and four men can pull the accordinfolded membrane along the roadway length. The 18- by 100-ft membrane surfacing can be placed by five men in less than 1 min. When the next section of membrane is placed, the ends to be joined are folded together in a French fold across the road width with a 1-ft overlap at the juncture. There is no reason to anchor the membrane when used beneath surfacing as the surfacing material will hold it in place.



Figure I13. The M8A1 mat anchored at lake edge with three anchors and cables



Figure 114. The M8A1 mat damaged by traffic in egress role

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